NSSDC NATIONAL SPACE SCIENCE DATA CENTER

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INTERNATIONAL SATELLITES FOR IONOSPHERE STUDIES

# ALOUETTE ISIS PROGRAM SUMMARY

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# Alouette-ISIS
# Program Summary

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National Space Science Data Center (NSSDC)/
World Data Center A for Rockets and Satellites (WDC-A-R&S)
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This Program Summary is dedicated
to the memory of John H. Chapman,
C. David Florida and Eldon S. Warren
in recognition of their major contributions
to the Alouette-ISIS satellite program.

CONTENTS

# I. FOREWORD

A program summary provides a valuable but, unfortunately, seldom available final report for a major research undertaking, representing the combined efforts of hundreds of scientists, engineers, technicians, and administrators over a period of a decade or more. The concept of the program summary, as developed at the National Space Science Data Center (NSSDC), includes not only a description of the objectives, spacecraft, experiments, and flight performance, but also a complete experiment-related bibliography along with a comprehensive assessment of the technological and scientific accomplishments. Such a document should provide a useful management tool with which the cost effectiveness of a scientific program can be measured. This should be valuable for the planning of future efforts, as well as for historical purposes.

The NSSDC facilities are unusually well suited for the compilation of program summaries. The comprehensive approach used by NSSDC for the archiving and distribution of satellite data has led not only to an extensive collection of data tapes, films and prints but also to a very complete documentation on spacecraft and experiments. The spacecraft documentation is in fact more complete than the acquisition of data at NSSDC, because it is usually initiated for all missions during the prelaunch hardware phase and it is available for all missions, whether or not data are ever deposited at NSSDC. This supporting documentation is computerized, and it includes complete descriptions of spacecraft and experiments. Also available at NSSDC is a computerized space science literature file containing about 36,000 literature citations coded according to satellite(s) and experiment(s). The task of producing a program summary can therefore be greatly simplified with the help of appropriate computer printouts from the above NSSDC files. Program-related papers and reports, which have not been published in scientific journals, can usually be found in the NSSDC microfiche file.

The first program summary produced at NSSDC was the *IMP Series Report/Bibliography*, prepared by Joseph H. King in December 1971. The second document of this type generated at NSSDC was the *OGO Program Summary*, compiled in two volumes. The first volume, dated December 1975, was prepared by John E. Jackson and James I. Vette. The second volume, prepared by John E. Jackson, was published in June 1978. Although the basic objectives of the IMP and OGO summaries were similar, the format, organization, and contents were quite different. The Alouette-ISIS program summary is also different from the two previous summaries. Its organization resembles that of the OGO summary, but many features found in the OGO summary are not included in the Alouette-ISIS summary. Thus, the present summary does not provide abstracts of the cited publications, nor does it include subject, author and corporate source indexes. Also omitted in the present report is a comprehensive discussion of scientific results. It is planned to include these in a later publication.

# Introduction

## II. INTRODUCTION

Prior to the launch of Alouette 1 (September 29, 1962), the ionosphere was virtually unknown above an altitude of about 400 km. The Alouette-ISIS satellites have provided a wealth of data concerning the morphology of the polar, midlatitude, and equatorial ionosphere to altitudes up to 3500 km. The measurements (which included not only electron density, but also plasma composition and temperatures) included all local times and all seasons, and encompassed a full range of solar activity. New knowledge was also acquired concerning the propagation and generation of electro-magnetic waves in the ionosphere at both radio and VLF frequencies. A large family of plasma wave phenomena was discovered and explained. Valuable data were also obtained concerning the flux of particles at energies ranging from 5 eV to 20 MeV. Last, but not least, spectacular results were achieved with the optical experiments on ISIS 2, which for the first time provided snapshots of the full auroral oval.

The previous paragraph merely hints at some of the scientific areas that have benefited significantly from the Alouette-ISIS data. The importance of the Alouette-ISIS program can also be appreciated from the fact that it represents 50 satellite-years of measurements in the terrestrial ionosphere, which have led to approximately 1000 publications.

Although articles based upon the Alouette-ISIS data continue to appear in the published literature, the majority of them have been written, and one is now able to assess the accomplishments of the program. Alouette 1 won recognition mainly through the success of the topside sounder, which alone led to 220 publications. Some additional interesting statistical data pertaining to the Alouette-ISIS literature will be discussed later. Much of the enormous volume of data obtained has been deposited in the World Data Centers where it has been made available to the scientific community for further studies and analysis. All of these factors have contributed to the major role which the Alouette-ISIS data have played in furthering our understanding of the near-earth environment.

The Alouette-ISIS program was a joint undertaking between Canada and the United States. Canada provided the Alouette and ISIS spacecraft, data acquisition, and satellite control. The USA provided the launch capability, tracking, and data acquisition. Satellite instruments and data processing support were provided by both countries. The USA also provided the Explorer 20 and Explorer 31 spacecraft that are considered part of the Alouette-ISIS program and are included in this summary. During the course of the program these countries contributed telemetry support and collaborative data analysis: Australia, Finland, France, India, Japan, New Zealand, Norway, and the United Kingdom.

The design of the Alouette 1 spacecraft was begun in 1959 at a very early stage of space technology, when satellite equipment and components were prone to failure, and most spacecraft had a lifetime of only a few months. Alouette was at least as complex as any spacecraft previously launched, and it incorporated large structures that had never been used in space before. The performance of Alouette 1 exceeded by far the most optimistic expectancies and its 10-year life established a longevity record. The other Canadian spacecraft of the program--Alouette 2, ISIS 1 and ISIS 2--have matched and surpassed this record. At least 90 percent of the Alouette-ISIS experiments have operated for at least 1 year and many of them considerably longer. Section III of this document provides a discussion of the objectives, history, spacecraft characteristics, mission profiles, technological accomplishments, and unique aspects of the Alouette-ISIS program.

Brief descriptions of the six spacecraft of the program and of the investigations on each are given in Section IV. All information in Section IV has been extracted from the NSSDC information system. The spacecraft are ordered by launch dates, and the investigations are listed according to their NSSDC ID number (see Appendix A).

Each spacecraft description entry in Section IV includes the spacecraft alternate names, NSSDC ID number, launch information (date, site, and vehicle), spacecraft weight, orbit parameters (type, epoch date, period, inclination, periapsis, and apoapsis), sponsoring country and agency, personnel (project manager, "PM"; project scientist, "PS"; and their affiliation at the start of the project), and a brief description concerning the mission. Additional information concerning the PM and PS codes is given in Appendix A. The "NLA" code that sometimes follows a person's name is explained in Appendix A. The brief description is followed by a spacecraft-related bibliography represented by a list of reference numbers. The citations corresponding to these reference numbers are found in Section V. For convenient reference to the bibliography, consecutive numbers have been assigned to each citation.

Each investigation description entry in Section IV includes the investigation name (as used by NSSDC), the NSSDC ID number, the name and current affiliations of the principal investigator (PI) and of the associated other investigator(s) (OI), and a brief description of the investigation. The principal investigators are listed first, but the other investigators are not listed in any particular order. The brief description is followed by an investigation-related bibliography represented by a list of reference numbers (see previous paragraph, last two sentences).

Section V contains the Alouette-ISIS bibliography, ordered alphabetically by first author's name. A few publications that have no author are listed ahead of the alphabetical sequence. This bibliography was generated from the NSSDC computerized space science literature file (see Foreword, second paragraph). The citations in the file can be searched by spacecraft, investigations, authors, titles, journals, publication dates, etc., and organized accordingly.

We conclude this section with some statistical information on the bibliography contained in Section V. Table 1 shows the journals where most of the Alouette-ISIS papers were published. It is seen that the leading journal was the *Journal of Geophysical Research*. A large number of papers also appeared in the *Proceedings of the IEEE* because a special issue of this journal in June 1969 was devoted to topside sounding, which was the principal research tool used on Alouette 1, Alouette 2, and Explorer 20.

| | |
|---|---|
| CAN. J. PHYS. | 44 |
| PROC. OF THE IEEE | 49 |
| GEOMAG. AERONOMY | 20 |
| GEOPHYS. RES. LETT. | 17 |
| J. ATMOS. TERR. PHYS. | 68 |
| J. GEOPHYS. RES. | 229 |
| NATURE | 29 |
| PLANET. SPACE SCI. | 49 |
| RADIO RES. LAB. J. (JAPAN) | 19 |
| RADIO SCIENCE | 31 |
| OTHERS (51 JOURNALS) | 134 |
| TOTAL | 689 |

TABLE 1. Alouette-ISIS Refereed Publications Sorted by Journal (as of July 1986)

Table 2 shows the distribution of the same publications by nations. The nationality assigned to a given paper was the same as the nationality of the sponsoring agency. Some prorating was done whenever authors of a given paper were sponsored by agencies in different countries. The final figures in Table 2 have been rounded off to whole numbers. It is seen that most of the publications originated in Canada and in the United States, followed by the United Kingdom, Japan, and surprisingly the USSR. Except for the USSR, the nations shown in Table 2 were active participants in the program, helping with

| | |
|---|---|
| CANADA | 238 |
| FRANCE | 24 |
| INDIA | 15 |
| JAPAN | 39 |
| NEW ZEALAND | 15 |
| UNITED KINGDOM | 43 |
| UNITED STATES | 254 |
| USSR | 34 |
| OTHERS (6 NATIONS) | 27 |
| TOTAL | 689 |

TABLE 2. Alouette-ISIS Refereed Publications Sorted by Nation (as of July 1986)

data acquisition, processing, and analysis. Papers originating in nations other than Canada and the United States were, in almost all cases, based upon the topside sounder data, because of the very well-known sounder technique and format. This technique had been used for ground-based studies of the ionosphere since the mid-thirties, and it was familiar to ionosphericists throughout the world when Alouette 1 was launched.

Table 3 provides further information on Alouette-ISIS publications based either partly or entirely on sounder data. It is seen that the percentage of papers based upon sounder data decreases steadily with each spacecraft of the Alouette-ISIS series. The total number of papers based entirely upon sounder data is about one order of magnitude greater on Alouette 1 than on ISIS 2. Yet the quality of the sounder data was significantly better on ISIS 2 than on Alouette 1. This comparison demonstrates clearly the importance of making the first comprehensive, synoptic measurements of a given parameter. Subsequent observations seldom have the same impact as did the first look at the unknown. Table 3 also reveals (indirectly) the broadening of the program with subsequent spacecraft. On Alouette 1 the sounder was the principal investigation. The three other experiments were included almost as an afterthought. On ISIS 2 the number of investigations had grown to 12; the importance of the new investigations was comparable to that of the sounder. Thus, the statistics of Table 3 reflect the steady increase in the scope of the Alouette-ISIS program. In contrast to publications based upon topside sounder data, where worldwide participation was evidenced, the publications based upon the other investigations were written almost entirely by the corresponding principal investigators and their immediate associates, reflecting the more specialized nature of the data reduction and analysis.

| | AL 1 | AL 2 | ISIS 1 | ISIS 2 |
|---|---|---|---|---|
| TOTAL PUBLICATIONS (REFEREED) | 302 | 176 | 116 | 178 |
| SOUNDER & OTHER DATA | 234 (77%) | 130 (74%) | 55 (47%) | 55 (31%) |
| SOUNDER DATA ONLY | 219 (72%) | 103 (58%) | 38 (33%) | 26 (15%) |

TABLE 3. Sounder Publications Compared to Total Publications and Percentage of Total

Tables 1, 2, and 3 were based upon refereed journal publications. A number of non-refereed, yet quite useful, publications appear in government, industry, and university reports, in proceedings of meetings (including books), and in the COSPAR publication, *Advances in Space Research*. The number of reports in the various categories is indicated in Table 4.

| | |
|---|---|
| PROCEEDINGS (AND BOOKS) | 129 |
| COSPAR | 34 |
| GOVERNMENT REPORTS | 83 |
| INDUSTRY REPORTS | 8 |
| UNIVERSITY REPORTS | 26 |
| TOTAL (NONJOURNALS) | 280 |
| TOTAL (REFEREED JOURNALS) | 689 |
| TOTAL (JOURNALS & NONJOURNALS) | 969 |

TABLE 4. Total Alouette-ISIS Publications (as of July 1986)

One last quantitative assessment of the Alouette-ISIS bibliography is presented by the data shown in Figure 1. The abscissa is time shown as calendar years for the period 1960 to 1985, and the ordinate is the cumulative number of experiment-related articles published in refereed journals. Superimposed on Figure 1 are boxes that are related only to the abscissa. The length of each box shows the period of time during which Alouette 1, Alouette 2, ISIS 1, and ISIS 2 were operating. The ISIS 1 and ISIS 2 boxes were left open to show that both spacecraft were still operating as of January 1, 1985. Actually, ISIS 1 and ISIS 2 were still operating at the time of this writing (May 1986). The altitudes indicated in the boxes for Alouette 2 and ISIS 1 are perigee and apogee, respectively. Only one altitude is shown for Alouette 1 and ISIS 2 since these spacecraft were in circular orbits. The four spacecraft were in similar near-polar orbits; therefore, inclination information was not included in the time-span boxes.

The top graph shows as a function of time the cumulative total number of Alouette-ISIS publications (including those based upon Explorers 20 and 31). Separate graphs are not included for Explorers 20 and 31, since these spacecraft were relatively short-lived and the resulting publications, although extremely important, represent a small percentage of the total Alouette-ISIS publications. Since publications were often based upon more than one spacecraft, such publications are included in the cumulative totals for each of the corresponding spacecraft. One could have arbitrarily assigned such multiple-spacecraft publications to the latest spacecraft. However, such an assignment would have been unrealistic, since in many cases the more important data source was an earlier spacecraft. In the case of Alouette 1, two graphs are given, one showing the number of publications based upon Alouette 1 only and the other showing the total number of publications related to Alouette 1 (i.e., Alouette 1 alone plus Alouette 1 combined with other spacecraft). To avoid overcrowding Figure 1, this two-graph presentation was not repeated for Alouette 2, ISIS 1 and ISIS 2. For these later spacecraft, only the total number of related publications has been shown. The graphs show that the Alouette-ISIS program has continuously produced scientific results for a period of time well in excess of 20 years.

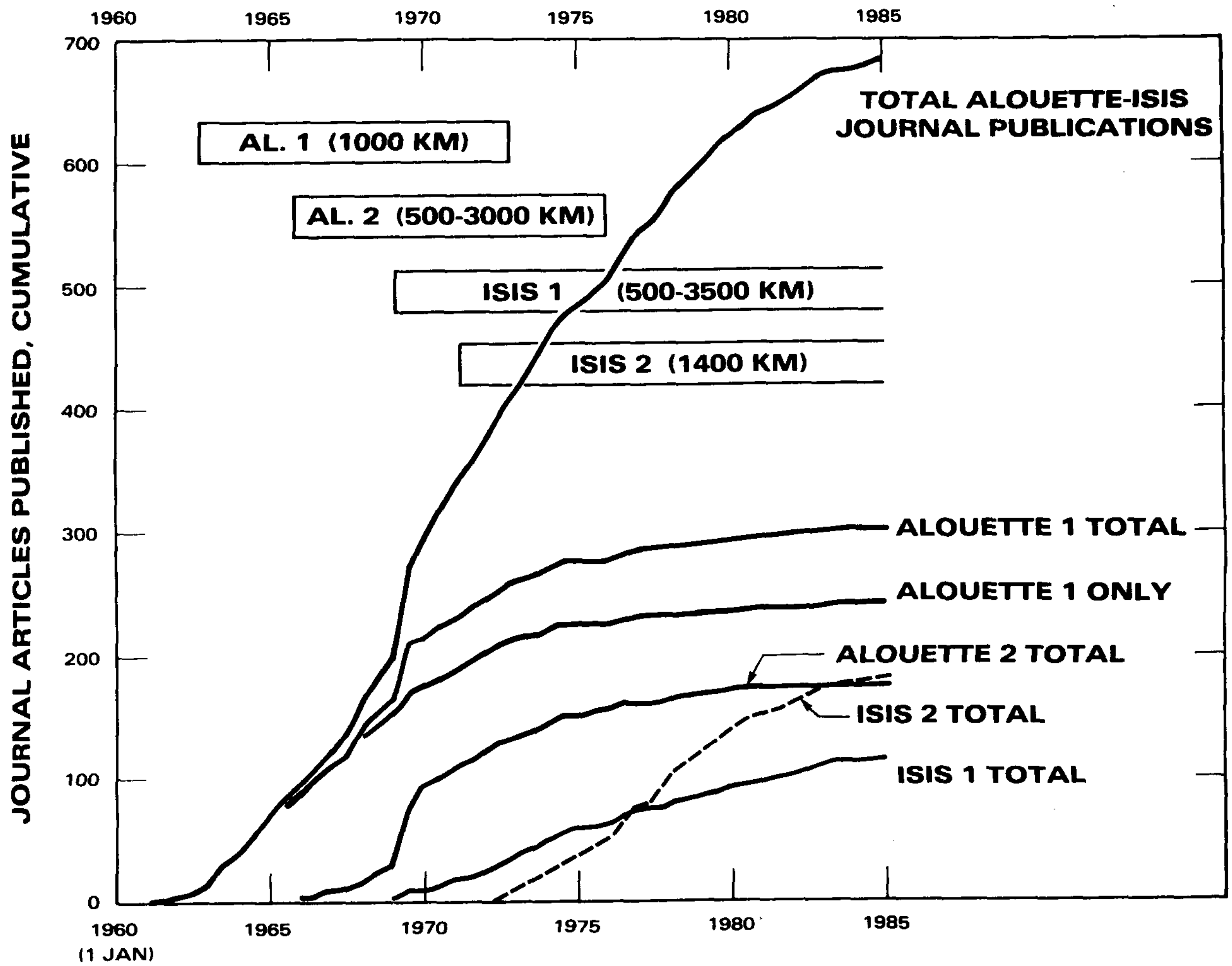


FIGURE 1. Alouette-ISIS Journal Publications

The total Alouette-ISIS publications graph reveals a very rapid increase in the number of publications that occurred in 1969. This was due mainly to the special issue of the *IEEE Proceedings* (June 1969) that included 46 papers based upon Alouette 1, Alouette 2, Explorer 20, and Explorer 31. It is of interest to note that about 40 papers based either partly or entirely on Alouette 1 were published during the period 1973 to 1983, i.e., during the 10-year period following the termination of Alouette 1 operations. Perhaps a proper environment for continued Alouette 1 studies was provided by the Alouette 2 and ISIS operations, which extended well beyond the termination of Alouette 1. Very little support is now available for Alouette-ISIS studies, and no significant further increase is expected in the total number of journal publications. This number was 682 on January 1, 1985, the cutoff date for Figure 1. The period January 1985 to July 1986 yielded only seven additional journal publications.

In view of the very close monitoring of Alouette-ISIS publications that has been done by the author since the beginning of the Alouette-ISIS program, and considering the very small increase in the number of publications during the past 18 months, it is reasonable to conclude that the present document provides an Alouette-ISIS bibliography that will be essentially complete for years to come.

# The Alouette-ISIS Program

## III. THE ALOUETTE-ISIS PROGRAM

### 1. Introduction

The Alouette-ISIS program is the one of earliest* and probably one of the best examples of international cooperation in space research by the National Aeronautics and Space Administration (NASA). Specific directives for such cooperation were included in the Congressional Act† which created the National Aeronautics and Space Administration (NASA) on July 29, 1958. When this legislation was enacted, the United States was one of 66 nations engaged in an unprecedented joint effort to understand the earth and its environment under the programs of the International Geophysical Year (July 1, 1957, to December 31, 1958). It is not surprising therefore that the Space Act of 1958 reflects the IGY spirit of international cooperation. One highlight of the IGY cooperation was the very successful U.S./Canadian rocket program conducted at Fort Churchill, Canada, which, in a sense, was a precursor to the Alouette-ISIS program.

A joint U.S./Canadian effort to investigate the global structure of the upper ionosphere was initiated at the end of 1958. The basic concept of the experimental approach was to explore the upper (or topside) ionosphere from a satellite by the same ionosonde (or sounder) technique which had been used for several decades from the ground. The satellite version of the ionosonde became known as the topside sounder (Franklin and Maclean, 1969), and, until 1963, the related U.S./Canadian effort was named the Topside Sounder Program. This program led to the first topside sounder satellite, Alouette 1,†† launched on September 29, 1962. This satellite was designed and built in Canada. The launch vehicle was provided by the United States. On December 23, 1963, Canada (the Defense Research Board) and the United States (NASA) agreed to a continued and expanded program of satellite studies of the ionosphere (International Satellites for Ionospheric Studies, ISIS). The expanded program led to three additional Canadian-built, U.S.-launched, satellites: Alouette 2, ISIS 1, and ISIS 2. The United Kingdom was involved in the program from the beginning. International participation was increased later to include France, Japan, and Norway after 1966; India, New Zealand, and Australia after 1971; and Finland after 1977. To date, over 50 research groups and agencies have made use of topside sounder data** to aid or supplement their own research. The topside sounder, however, was only one of many experiments included in the Alouette-ISIS program. The satellites of the series (Alouette 1, Explorer 20, Alouette 2,

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*A cooperative effort between NASA and the United Kingdom led to the successful launching of Ariel 1 on April 26, 1962, making Ariel 1 the first international satellite of NASA.

†The National Aeronautics and Space Act of 1958, sections 102 and 205.

††The name "Alouette," the French word for a high-flying bird, the lark, has connotations that extend deep into early Canadian colonial history. It is also the title of one of the country's best known and most nonsensical folk songs, originally brought to North America from France many centuries ago.

**Analysis of topside sounder data (topside ionograms) yields ionospheric electron-density versus altitude from the satellite height down to the height of maximum electron-density hmaxF2 (located typically at 300 km), as well as a wealth of information concerning plasma and propagation effects.

Explorer 31, ISIS 1, and ISIS 2), particularly the last two, contained a diversity of mutually supporting experiments, selected to provide a more complete understanding of the ionosphere. Collectively, these satellites have provided continuous observations of the topside ionosphere from 1962 until now (1986), representing over 50 satellite-years of ionospheric data.

The overall coordination of the program was provided by an international Working Group, which was named the Topside Sounder Working Group from January 1960 until December 1963 and later was known as the ISIS Working Group. The Working Group has provided (for over 20 years) the framework for the extensive international cooperation which was unquestionably the most important factor for the remarkable success and duration of the program.

## 2. History

The history of topside sounding appears to have begun in July 1958, when the Space Science Board of the National Academy of Sciences of the United States, under the chairmanship of L. V. Berkner, sent out a request for suggestions for satellite experiments. At a meeting in October 1958, called by H. G. Booker of Cornell University to discuss ionospheric experiments in satellites, a number of groups in the United States and Canada indicated an interest in topside sounding. In particular, this meeting stimulated a proposal from the Defense Research Telecommunications Establishment (DRTE) at Ottawa, Canada, which came to NASA at the end of 1958. NASA accepted the proposal as a joint undertaking between Canada and the United States, each country paying its own costs in the project. Canada agreed to supply the satellite instrumentation and the United States the launch vehicle. The United States also agreed to provide tracking and telemetry support from a number of NASA stations which eventually included (at the time of the Alouette 1 launch) Antofagasta, Chile; College, Alaska; East Grand Forks, Minnesota; Fort Myers, Florida; Quito, Ecuador; St. John's, Canada; South Point, Hawaii; Winkfield, England; and Woomera, Australia. Canada was to establish telemetry stations needed in Canada (at Ottawa, Ontario; Prince Albert, Saskatchewan; and Resolute Bay, Northwest Territories). A joint announcement of this arrangement was made by both countries on April 20, 1959. Canada subsequently assumed full responsibility for the topside sounder spacecraft with the exception of the environmental tests which were conducted at the Goddard Space Flight Center (GSFC).

Concurrently, NASA had requested that the Central Radio Propagation Laboratory (CRPL) of the National Bureau of Standards, Boulder, Colorado, examine the topside sounder proposals received by NASA for scientific merit and engineering feasibility and recommend immediate and long-range approaches to this area of research. In June 1959, a CRPL study report recommended the fixed-frequency system as a first-generation experiment and suggested that DRTE be encouraged to develop its swept-frequency system as a second-generation experiment. This second recommendation was, in fact, a concurrence by CRPL with the decision already reached between NASA and DRTE. NASA accepted the CRPL recommendation to develop the fixed-frequency topside sounder at the same time as the swept-frequency sounder. This project was started in 1960 and placed under the scientific supervision of CRPL. GSFC was made responsible for the NASA management of the two topside sounder projects. In view of the similarity of objectives and techniques in the two projects, a joint working group was set up early in 1960.

The United Kingdom then expressed an interest in participating in the topside sounder program. Under an arrangement of March 1961, the United Kingdom agreed to support the program by operating telemetry stations in the South Atlantic and Singapore. In return for this assistance, the Radio Research Station (RRS) at Slough, England, was given immediate access to the topside sounder data.* The early cooperative agreements between Canada and the United States were extended in 1964 to include the ISIS program. The RRS participation also was extended subsequent to this new agreement. The international participation was increased during 1965 and 1966 to include agencies in France, Norway, and Japan; in 1971 and 1972 to include agencies in India, New Zealand, and Australia; and in 1977 to include Finland. Specific arrangements differed in detail, but basically all these nations have supported the program by providing telemetry services and by participating in the reduction and analysis of topside ionograms. The French telemetry stations used in the Alouette-ISIS program include Brazzaville, Congo; Bretigny, France; Colomb Bechar, Algeria; Kerguelen Island; Kourou, French Guyana; Las Palmas, Canary Is.; Ouagadougou, Upper Volta; Pretoria, S. Africa; and Terre Adelie, Antarctica. Other nations have provided telemetry services at Tromso (Norway), at Kashima (Japan), at Ahmedabad and Thumba (India), at Lauder (New Zealand), at Darwin (Australia), and at Sodankyla (Finland).

The phenomenal growth of the international participation has resulted in the creation of an ISIS telemetry network (outside of the NASA telemetry network) which became capable of acquiring most of the data desired from the Alouette-ISIS satellites. Consequently, in the early seventies, NASA reduced considerably its telemetry support of the ISIS program. A complete list of telemetry stations used in the ISIS program is given in Tables 5 and 6, at the end of Section III. These tables show the status as of March 9, 1984, which is the date when ISIS operations were terminated in Canada. The Radio Research Laboratories (Tokyo, Japan) then requested and received permission to reactivate ISIS 1 and ISIS 2. Regular ISIS operations were started from Kashima, Japan, in early August 1984. The ISIS data processing facilities in Ottawa were kept operational until March 1985.

### 3. Working Group

The Topside Sounder Working Group, later to become the ISIS Working Group, was organized to coordinate and guide the rather diverse activities involved in planning and implementing an international program of ionospheric sounding from satellites. In Working Group meetings both the scientific goals of the program and the proposed solutions to the associated engineering problems were debated. A valuable consequence has been that the scientific, engineering, and administrative personnel involved developed an understanding of all the important issues.

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*In the sixties, when a new satellite was launched, the scientific data were considered proprietary to the principal investigators for a reasonable period of time, usually 1 year. After the proprietary period the data were usually made available to the scientific community. Participants in the Alouette-ISIS program were, in effect, given principal investigator status.

The Working Group was concerned with the typical scientific, engineering, and operational problems of a satellite project. In addition, the Working Group had to devise, recommend, and carry out preliminary space investigations to establish the feasibility of topside soundings and to obtain a number of design parameters which previously were unknown. For example, it was evident when the project was initiated that the topside sounder would require antennas about one order of magnitude longer than previously had been used on space vehicles. Major advances in the existing technology were needed to build suitable antennas, and the reliability of the proposed system had to be established. Since the space environment could not be suitably simulated on the ground, the Working Group recommended that a special rocket test be conducted to test these unusually long antennas. Also, the power required from the sounder transmitter was unknown because the reflection coefficient of the topside ionosphere and the level of ambient noise at the sounding frequencies were both unknown. A radiometer for measuring the intensity of radio noise in the topside ionosphere at 3.8 MHz was constructed and installed in Transit 2A (Chapman and Molozzi, 1961), which was launched on June 22, 1960. The measured value of the cosmic noise provided the required design information.

On June 14, 1961, a rocket test was made of the technique of extending from a spinning vehicle the 75-ft antennas required for efficient radiation of the sounder transmissions (Molozzi and Richardson, 1967). Two antenna units were flown on the rocket; one of the antennas extended its full length, the other extended three-quarters of its length. The engineering information obtained was adequate for specifying the modifications required in the final mechanical design of the antennas used in the Alouette and Explorer 20 satellites. Feasibility of the topside sounding technique was established by rocket tests instrumented by Airborne Instruments Laboratory (AIL). Each of the rockets carried one or more fixed-frequency sounders. The first was launched on June 24, 1961, during the day into a quiet ionosphere that had smooth reflection surfaces; the second was launched on October 31, 1961, at night into moderately disturbed ionospheric conditions during spread F (Knecht et al., 1961; Knecht and Russell, 1962). The required engineering information was obtained and, in addition, important new phenomena were observed. The first of these rockets obtained evidence of plasma resonance phenomena; the second provided the first strong evidence of ducted propagation along the magnetic field in the ionosphere. A third rocket, launched to observe the properties of the topside winter ionosphere, failed; the heat shield did not detach.

The Working Group has also contributed significantly to the optimum use of the Alouette-ISIS satellites, by coordinating the acquisition, processing, publication and exchange of the data. Periodic reporting by the member organizations of technical and scientific developments has provided the information necessary for effective collaboration between experimenters, especially between those associated with different experimental equipment. Fifty Alouette-ISIS Working Group meetings were held during the period January 1960 to September 1972. A comparable number of separate engineering or experimenters' meetings have also been held, representing a more specialized extension of the Working Group activities. During the period January 1973 to December 1980, Working Group meetings were held approximately once a year, and Experimenters' meetings were held about three times per year.

## 4. Objectives and Mission Profiles

The broad objectives of the Alouette-ISIS program were to conduct a comprehensive synoptic study of the topside ionosphere over a complete range of solar activity, and to provide the basis for a theoretical understanding of the observations. The discussion of objectives and mission profiles does not include detailed descriptions of spacecraft and experiments. This information is given in Section IV of the *Alouette-ISIS Program Summary*. The present discussion is concerned primarily with the scientific purposes of the various missions, with the various technological problems encountered, and with the methods used to solve these problems.

### 4.1 Alouette 1 (launched September 29, 1962)

The primary purpose of the Alouette 1 mission was to investigate the geographic and diurnal properties of the topside ionosphere at altitudes up to 1000 km. These considerations led to the choice of a circular orbit at 1000 km with an inclination of 80 deg prograde which provided a complete coverage of all geomagnetic latitudes, while making it still possible to achieve a diurnal variation in a period of 3 months. Design parameters for the sounder were based partly upon existing knowledge and partly upon additional space experiments conducted primarily to supply the needed design data. The maximum sounder frequency was based upon the known maximum densities to be encountered at hmaxF2, while the minimum sweep frequency was essentially the minimum gyrofrequency at 1000 km. This made it theoretically possible to obtain echoes through the total altitude range on at least the extraordinary mode. Secondary objectives included cosmic noise measurements, VLF studies and energetic particle investigations (electrons in the 40 keV to 3.9 MeV energy range; protons in the 0.5 to 700 MeV energy range).

Satellite technology was still in its infancy when the design of Alouette 1 was initiated by the Canadian Topside Sounder Group at DRTE, Ottawa. To optimize the chances of success, undue complexity was avoided in the payload design, and redundancy of vital components was stressed. Thus, data storage was not provided in the spacecraft, but spare batteries were included. The conservative approach used in the design led to the remarkable 10-year life of Alouette 1. One consequence of the decision not to have satellite-borne data storage was that provisions had to be made for a large network of telemetry stations. Operation of the satellite (for 10-minute periods) was initiated by a command signal from the ground, when the satellite came within the telemetry range of a ground station and when the turn-on had been scheduled by the satellite controller. The master ground station was at DRTE (now CRC*), Ottawa, and it was there that the satellite controller monitored the engineering status of the spacecraft and prepared operating schedules. The Ottawa station also transmitted the more complex commands such as those required to switch spare batteries or to select certain operating modes.

*DRTE was transferred in April 1969 to the newly formed Department of Communications, and DRTE became known as the Communications Research Centre.

One complexity which could not be avoided was the sounder antenna system which had to be capable of radiating efficiently signals in the frequency range from 0.5 to 12 MHz. To satisfy this requirement, extremely long antennas had to be provided. A dipole 45.7 meters long was used for the band 0.5 to 5 MHz, while one 22.8 meters long was used from 5 MHz upward. The two dipoles were perpendicular to the spin axis and to each other. Such long antennas had never been used previously on a satellite, and the successful mechanical design of these antennas represents a unique and major contribution to the field of spacecraft engineering (Mar and Garrett, 1969).

Alouette 1 was spin-stabilized with the spin axis (at the time of launch) normal to the plane of the ecliptic. The initial spin rate after antenna deployment was 1.4 rpm. The spin rate, however, decreased at a much faster rate than expected and it was down to 0.9 rpm at the end of 1 year (Mar and Garrett, 1969). After a few years, this rapid decay in spin rate caused Alouette 1 to become gravity-stabilized with the long antennas aligned with the local vertical. The spin rate decay did not, however, cause a significant loss of data.

### 4.2 Explorer 20 (launched August 25, 1964)

The fixed-frequency topside sounder satellite, Explorer 20, was developed in the United States as a part of the International Topside Sounder Program. The spacecraft was built at the Airborne Instruments Laboratory (AIL), Deer Park, N.Y., and the data analysis was done at CRPL. Explorer 20 was conceived initially as a first-generation topside sounder satellite because of its simplicity relative to Alouette 1. The Explorer 20 sounder was designed for operation at only six fixed frequencies, namely 1.5, 2.0, 2.85, 3.72, 5.47, and 7.22 MHz. These frequencies were spaced logarithmically to optimize the resulting low-resolution sampling of the exponentially shaped topside profile. The CRPL/AIL sounder was designed to complete its 6-frequency sounding in 1/10 s, during which time the satellite would travel less than 1 km along its orbit. The time required for a complete sounding on Alouette 1 was about 5 to 10 s, corresponding to a horizontal displacement of 35 to 70 km. Thus, the Explorer 20 sounder was designed to provide a horizontal resolution considerably greater than that of Alouette 1. The frequency resolution (or, equivalently, the vertical resolution), however, was two orders of magnitude greater on Alouette 1, since approximately 700 discrete and closely spaced frequencies were used on Alouette 1 during the complete 0.5 to 12.0 MHz sweep. Clearly, the two sounder techniques were complementary.

The Explorer 20 spacecraft was built on a schedule paralleling that of the Canadian Alouette 1 spacecraft, and the Explorer 20 launch was planned for the summer of 1962, i.e., slightly ahead of the Alouette 1 launch. The Explorer 20 program, however, was delayed by problems with the Scout launch vehicle, and the Canadian satellite was launched first. The fixed-frequency topside sounder was continued in spite of the successful launch of Alouette 1 and the excellent in-orbit performance of the Canadian sounder, because of the complementary nature of the two sounder techniques.

Explorer 20 was launched into an orbit similar to that of Alouette 1 and it has provided useful data for the period August 1964 to January 1966. The fixed-frequency sounder has yielded data on the fine structure of ionospheric irregularities and plasma resonances which are impossible to obtain with a swept-frequency sounder. The fixed-frequency sounder data also could be used to calculate the electron-density (N) as a function of height (h) (Lawrence and Hallenbeck, 1965). The Alouette 1 ionograms, however, were plentiful* and much better suited for N(h) calculations. Consequently, the data from the Explorer 20 sounder were used almost exclusively to study small-scale ionospheric irregularities and the fine structure of plasma resonances.

The Explorer 20 spacecraft also included a spherical ion probe designed to measure ion concentrations and ion temperatures in the immediate vicinity of the satellite. Experiments of this type that provide various parameters of the ambient medium (such as density, temperature, and composition) by using sensors at the satellite surface are known as direct measurement experiments. These experiments require that local disturbances be minimized in the vicinity of the sensors. These disturbances are due primarily to electrical potentials on the surface of the spacecraft. Theoretical considerations indicated that these effects might be sufficiently minimized at the sensor locations by the use of blocking capacitors at the antenna feed points, which would isolate the VxB potentials induced on the large antennas.

The spherical probe on Explorer 20 was the first attempt to combine direct measurements with topside soundings on a satellite. Although ac-coupling was used to connect the sounder antennas to the spacecraft, this proved to be inadequate and most of the spherical probe data were unusable. The topside sounder project, however, benefited from this experience, and sheath guards were added to the sounder antennas on Alouette 2.

### 4.3 ISIS X (launched November 29, 1965)

The primary purpose of the ISIS X mission was to extend the scope of the Alouette 1 mission both in altitude coverage and in the number of ionospheric parameters to be investigated. Secondary objectives included cosmic noise measurements, VLF studies, and energetic particle investigations. The new ionospheric parameters to be measured included electron temperature, ion temperature, and ion composition. These parameters are most readily obtained using direct measurement techniques, and a sufficient number of these techniques were incorporated in the ISIS X mission to provide at least two independent measurements of each parameter. As explained earlier, a difficult spacecraft potential problem had to be overcome in order to conduct successful direct measurements on a satellite containing a topside sounder. Although the blocking capacitors used on Explorer 20 between the spacecraft and the antennas did not solve this problem, the use of these capacitors was a step in the proper direction. Additional precautions taken in the ISIS X design included the use of sheath guards on the sounder antennas and the use of insulation on the spacecraft skin of all exposed metallic surfaces with nonfloating potentials (such as the solar cell interconnections).

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*During the first 3 years in orbit, Alouette 1 was providing topside ionograms at the rate of 1100 ionograms per day.

Modifications also were made to the antenna system in an attempt to correct the excessive spin rate decay experienced on Alouette 1. A theoretical study by Etkin and Hughes (1967) indicated that the observed spin decay on Alouette 1 could be explained by taking into consideration the flexibility of the long antennas. When this was done, additional de-spin torques were obtained from the action on the antennas of (1) the combination of the thermal and pressure fields of the sun, and (2) the combination of the thermal field of the sun and atmospheric drag. The temperature difference between the sunlit side of the antenna and the shadow side causes differential expansion and bending of the antenna. As a result, the center of mass and the center of pressure separate, allowing the Alouette satellites to experience torques due to solar radiation pressure and also due to atmospheric drag when below 1000 km. To counteract the solar radiation de-spin torque on ISIS X, highly reflective end plates were installed on the ends of the long antennas. The high reflectivity ensured that most of the incident radiation was reflected specularly, resulting in a net spin-up torque on the satellite.

The ISIS X objectives required that the sounder experiment be extensively modified. Since the sounder would operate during a period of increasing solar activity, the maximum density in the ionosphere would be greater than for Alouette 1, and the highest frequency of the sounder had to be raised to 13.5 MHz. On the other hand, the much higher apogee planned for ISIS X would bring the sounder into regions of much lower electron density and magnetic field, requiring that the lowest frequency of the sounder be reduced from 0.5 to 0.2 MHz. The decision to reduce the lower frequency limit required in turn that the length of the longer sounder antenna be increased from 45.7 to 73.0 meters.

The ISIS X mission was designed to test the spacecraft modifications outlined above, while at the same time ensuring that the basic scientific objectives would be met. This was accomplished by launching two satellites simultaneously into the same orbit (3000 km apogee, 500 km perigee, 80 deg inclination): Alouette 2* (a modified version of Alouette 1) and Explorer 31** (Direct-Measurements Explorer A or DMEA), a spacecraft of shape and size known to be suitable for local sensing of ionospheric parameters. For the safe placement in orbit and deployment of spacecraft appendages, the two ISIS X spacecraft had to be provided with a small but sufficient separation velocity. A separation velocity of 8.75 km per day was achieved, resulting in a period of about 4 months during which the two spacecraft could perform essentially simultaneous measurements. This "close proximity" period turned out to be five times longer than specified. One of the Explorer 31 temperature probes was duplicated on Alouette 2, and comparison between the two identical experiments showed that the Alouette 2 structure would be satisfactory for direct sensing experiments.

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*Alouette 2, like Alouette 1, was designed and built at DRTE, Ottawa.

**Explorer 31 was designed and built at the Applied Physics Laboratory (APL), Silver Spring, Maryland.

In keeping with the conservative approach used to ensure the success of the ISIS X mission, undue complexity again was avoided and redundancy of critical components was emphasized. For example, there was no provision for data storage on either Alouette 2 or Explorer 31, but spare batteries were included in both spacecraft. The lack of data storage facilities in the ISIS X spacecraft required that a large network of telemetry stations be used with Alouette 2 and Explorer 31. The ISIS X mission utilized essentially the same telemetry network as that used for Alouette 1. In some cases, the telemetry station capability had to be increased to permit simultaneous command and telemetry of Alouette 2 and Explorer 31. The Alouette 1 master station at DRTE, Ottawa, was used also as the Alouette 2 master station. It was at DRTE that Alouette 2 housekeeping data were obtained and more complex commands were executed. The master station for Explorer 31 was the APL station at Laurel, Maryland. The satellite controller at the APL station monitored the operational status of Explorer 31 and issued the special commands required for housekeeping and attitude control.

To optimize the direct measurements on Explorer 31, an elaborate magnetic attitude stabilization and control system was included on this satellite. The magnetic spin-up system was designed to maintain a 3-rpm spin rate with less than a 10 percent duty cycle of the attitude control system. The spin-axis orientation system was designed to maintain the spin axis orthogonal to the orbital plane. The detectors were mounted perpendicular to the spin axis.

The ISIS X mission achieved all of its scientific and technological objectives. The modifications made to the Alouette 2 antenna system reduced the spin rate decay by one order of magnitude, showing that the highly reflective end plates installed on the long Alouette 2 antennas had effectively counteracted any rapid de-spin of this satellite. The success of the ISIS X compatibility test showed that the Alouette 2 structure was satisfactory for direct measurements. The next step was to combine all the measurements on a single spacecraft. This was done on ISIS 1.

## 4.4 ISIS 1 (launched January 30, 1969)

The objectives of ISIS 1 were to make measurements similar to those of ISIS X during a period of maximum and declining solar activity. The selected ISIS 1 orbit (3500 km apogee and 565 km perigee), therefore, was similar to that of the ISIS X satellites. The ISIS 1 objectives had to be accomplished with a single spacecraft instead of the two satellites required for the ISIS X mission. One advantage of the single spacecraft approach was that simultaneous measurements would no longer be limited to a few months of "close proximity" as was the case for ISIS X. In fact, based upon the performances of Alouettes 1 and 2, it seemed likely that the ISIS 1 mission could provide simultaneous measurements for several years. Therefore, comprehensive ionospheric data were desired from ISIS 1 over essentially the same altitude range and geographic areas as those selected for the ISIS X mission. In addition, data were also desired from several very large areas of the world which could not be explored by the previous satellites of the series, since only real-time telemetry was available for the earlier missions.

The ISIS 1 spacecraft included basically the same experiments as those of ISIS X. In addition, it contained a fixed-frequency sounder similar to that of Explorer 20, a VLF transmitter used to excite various VLF phenomena in the vicinity of the spacecraft, a Beacon experiment, and instrumentation to measure electrons and positive ions in the 10 eV to 10 keV energy range. This last addition represented both an increased awareness of the importance (to ionospheric phenomena) of particles in this energy range and an increased emphasis on the development of suitable technology to make the required measurements. The ISIS 1 objectives required a spacecraft far more complex than the earlier spacecraft of the Alouette-ISIS program. The ISIS 1 satellite was the first of the Alouette-ISIS series to incorporate the following features: (1) swept- and fixed-frequency sounder techniques combined with a complete set of direct measurements; (2) active spin maintenance and spin-axis attitude control; and (3) onboard data storage. To meet these new requirements the spacecraft design used on Alouette 2 had to be extensively modified. New facilities had to be added to the ISIS 1 spacecraft, and the capabilities of earlier facilities had to be greatly expanded.

When the design of the ISIS 1 spacecraft was initiated (1964), the results of the ISIS X mission were not yet known. However, the spacecraft potential problem was sufficiently understood to expect a successful compatibility test on ISIS X and to proceed with plans for a complete selection of direct measurement experiments on ISIS 1. The theory of the antenna spin decay on Alouette 1 was still in a tentative stage, and even if the passive spin decay compensation planned for Alouette 2 were successful, changes in spin-axis orientation were a certainty and these changes would be excessive for direct measurement experiments. Active spin rate and attitude controls, therefore, were incorporated in the ISIS 1 spacecraft. Magnetic torquing techniques were used to control the spin rate within the range 1 to 3 rpm and to correct the spin-axis attitude (when necessary) at a rate of 3 deg per orbit.

The spacecraft tape recorder was a 4-track unit capable of storing data from all ISIS 1 experiments simultaneously for several periods, for a total of 64 min. The playback data were telemetered to the master ground station at DRTE. The playback speed was four times the recording speed. In order to acquire data over locations inaccessible to the ground-based telemetry network, it was necessary to provide an onboard programmer that could switch on the desired experiments and the tape recorder at pre-selected times. A total of five commands could be stored together with their times of execution. These commands could be selected from a group of 10. The actual times at which the data were obtained by the tape recorder were provided by a clock that could be reset. The greater number of experiments to be controlled on ISIS 1, the addition of a programmer and clock, and provisions for active spin and attitude controls required that the command capability be expanded from the 24 commands used on Alouettes 1 and 2 to the 216 commands used on ISIS 1.

The primary data acquisition system for ISIS 1 continued to be the telemetry network used for Alouette 1 and for ISIS X. The tape recorder data were intended to be supplementary and obtainable without causing a reduction in the primary data acquisition. This was achieved by providing an additional telemetry link operating at 400 MHz and having a bandwidth of 500 kHz. This wide-band telemetry system also could be used to transmit real-time sounder or

VLF data in the event of a failure of the wide-band 136 MHz telemetry link. Finally, to operate the additional experiments and spacecraft systems, the power system had to be greatly enlarged. The number of solar cells (n-on-p type) was increased from 6480 (Alouettes 1 and 2) to 11,000 (ISIS 1). It is seen from the above discussion of the spacecraft experiments and systems that the ISIS 1 satellite was much more complex than its predecessors. The greater complexity also resulted in a significant weight increase from 145 kg (Alouettes 1 and 2) to 241 kg (ISIS 1).

Another very important difference between ISIS 1 and the Alouette satellites was in the basic approach used for the design and construction of the ISIS 1 spacecraft. With the exception of the sounder antennas which were manufactured by de Havilland Aircraft of Canada, Ltd., and with the exception of some standard components available commercially, Alouettes 1 and 2 were both completely designed and built at DRTE, a laboratory operated and staffed by the Canadian government. The ISIS 1 spacecraft, on the other hand, was built almost entirely by Canadian industry under contract to DRTE. The prime contractor was RCA Victor (RCAV), Ltd., Montreal. SPAR Aerospace Ltd., Toronto, provided the mechanical structure and the sounder antennas. Thus, with the ISIS mission, private industry in Canada became a major participant in the Canadian space program. The overall management of the ISIS 1 mission, however, remained at DRTE. A close cooperation established between DRTE and RCAV ensured that RCAV derived maximum benefit from the extensive experience with space technology available at DRTE.

ISIS 1 has now (1986) been operating for over 17 years, and its longevity has exceeded the 10-year records of Alouettes 1 and 2. Because of its long life, ISIS 1 was also able to provide data during the 1975-1976 sunspot minimum and to participate in the IMS program (International Magnetospheric Study, January 1, 1976, to December 31, 1979). The ISIS 1 satellite was the oldest of the 27 IMS satellites.

### 4.5 ISIS 2 (launched April 1, 1971)

The official Canadian/U.S. statement of the ISIS 2 mission was as follows: "To inject the spacecraft into a near circular earth orbit which will permit the study of the topside of the ionosphere above the electron peak of the F region. To continue and extend the cooperative Canadian/U.S. program of ionospheric studies initiated by Alouette 1 by combining sounder data with correlative direct measurements for a time sufficient to cover latitudinal and diurnal variations during a period of declining solar activity."

An eccentric orbit such as the one selected for ISIS 1 was excellent for the exploratory purposes of the ISIS 1 mission, but it was not well suited for the ISIS 2 mission which stressed the study of latitudinal effects. When direct measurements were made on ISIS 1, it was often very difficult to separate latitude and altitude effects. The complete latitudinal (pole-to-pole) variation of the vertical electron-density distribution could not be satisfactorily derived from the ISIS 1 sounder data. At perigee, the sounder data were very limited in altitude range; and at apogee, they suffered from poor resolution. A circular orbit at 1400 km, which avoids these problems, was found best suited for the ISIS 2 mission.

To fulfill the primary objectives, measurements were planned to study: (1) the distribution of free electrons and of the various species of ions as a function of time and position; (2) ionospheric irregularities such as spread-F and field-aligned ionization; (3) the composition and fluxes of energetic particles that interact with the ionosphere; and (4) the velocity distribution of thermal electrons and ions. The ISIS 2 spacecraft included basically all the ISIS 1 experiments plus two new ones. Of the 10 experiments similar to those on ISIS 1, eight were almost identical and two provided essentially the same information as their ISIS 1 counterparts but with different instruments. Many of the additional objectives of ISIS 2, therefore, were similar to those of ISIS 1, including cosmic-noise measurements, VLF studies, and energetic particle investigations. The two new experiments were designed to study atmospheric optical emissions at 6300, 5577, and 3914 A. The optical experiments also required a circular orbit and attitude control.

Due to budgetary constraints, the design changes on ISIS 2 were kept to a minimum. Consequently, as many systems and units as possible from ISIS 1 were incorporated in the design of the ISIS 2 spacecraft. Thus, attitude control, telemetry, command, data storage, and antenna and power systems on ISIS 2 were essentially the same as those of ISIS 1. A few changes were made in the sounder design to increase accuracy (onboard range marker and amplitude calibration), output power (two 400-W power amplifiers) and versatility (mixed mode, VLF/sounder mode, AIT mode). The AIT (Automatic Ionogram Transmission) mode allowed for the automatic operation of the sounder system once every 3 minutes. This gave an opportunity for small institutions to acquire topside ionograms with low-cost telemetry stations. The scope of the VLF experiment was increased to include antenna impedance measurements (sounder short dipole antenna measurements). The addition of two experiments and the various new features added to the previous experiments led to a slight increase in spacecraft weight from 241 kg on ISIS 1 to 256 kg on ISIS 2. The ISIS 2 spacecraft was built by Canadian industry under the same contractual arrangements as were used for the design and construction of ISIS 1.

The ISIS 2 mission was initiated in 1971 during a period of declining solar activity, and it has continued through the subsequent 1975-1976 sunspot minimum. In order to give the various ISIS 2 experiments the opportunity to acquire data under their "optimum operating conditions," the orientation of the spacecraft axis has been changed periodically from an orientation perpendicular to the orbital plane (cartwheel orbit) to an orientation parallel to the orbit plane (orbit aligned). It took about 10 days to accomplish these orientation changes. During this 10-day period, the orientation was unfavorable for most of the experiments, and the power available for experiments was significantly reduced. The orientation was changed typically once every 3 months. Thus about 10 percent of the total operational life of the satellite was spent for orientation maneuvers. The ISIS 2 satellite has now (1986) been operating for over 15 years, and it has participated in the IMS program with 10 of the 12 experiments still fully operational and with all spacecraft systems (except for the data storage capability) also fully operational. The ISIS 2 satellite has provided a unique and most comprehensive combination of experiments for ionospheric, auroral, and magnetospheric studies.

5. Summary of Technological Accomplishments

The scientific and technological objectives of the Alouette-ISIS program were met and exceeded in all five missions. The technological accomplishments include

(1) the first launch of a NASA satellite from the Western Test Range (California);
(2) near-perfect orbits for all missions;
(3) near-perfect spacecraft performance for all missions;
(4) very high percentage (>90%) of successful experiments;
(5) a major breakthrough in the design of extremely long extendible spacecraft antennas;
(6) perfect deployment in orbit of these antennas;
(7) superiority of this new antenna design as evidenced by its adoption and extensive use in many other space programs;
(8) the development of techniques to overcome the very severe spacecraft potential problem caused by extremely long spacecraft antennas;
(9) major progress in the understanding of long spacecraft antenna dynamics leading to the invention of a passive spin-control technique;
(10) the first (and successful) use of sounder techniques in a satellite;
(11) the first successful combination of sounder and direct measurement techniques, two techniques formerly considered to be incompatible;
(12) the extraordinary longevity of Alouettes 1 and 2 (10 years of operation each) and the continued operation of ISIS 1 and 2 in 1986 after 17 and 15 years in orbit, respectively;
(13) the extraordinary longevity of the Alouette-ISIS program, which is still active after 24 years.

6. Unique Aspects of the Alouette-ISIS Program

For many reasons, the Alouette-ISIS program is probably the most outstanding of the international programs of NASA. The efforts of the unusually competent and dedicated members of the Canadian team, together with the wholehearted support of their U.S. counterparts, led to Canada's spectacular entry into the space age with Alouette 1 on September 29, 1962. The Canadian space program has since then maintained an unequaled record for overall excellence, in both the scientific and applications areas.

The summary of technological accomplishments given above did not take into consideration the international aspect of the Alouette-ISIS program. This aspect of the program also includes an impressive number of accomplishments.

(1) Alouette 1 was the first spacecraft completely designed and built by a nation other than the United States or the Soviet Union.
(2) The Canadian-built Alouette 1 was as complex as any previously launched U.S. or USSR satellite.
(3) The longevity of Alouette 1 was far greater than that of any previously launched satellite.

(4) Until the early seventies, Alouette 1 was the satellite that had led to the greatest number of scientific publications. A comparable publication record has been achieved more recently by very large orbiting observatories such as OGO 5.

(5) The success of Alouette 1 was equaled, if not surpassed, by that of Alouette 2, ISIS 1, and ISIS 2, the other Canadian-built satellites of the program.

(6) Since it is essentially as old as NASA itself, the Alouette-ISIS program has lasted longer than (or as long as) any other NASA program.

(7) The program which started as a joint effort between Canada and the United States grew steadily to include a total of 10 nations. All participating nations provided telemetry stations, many of which were built specially for the Alouette-ISIS program. The average length of this participation has been about 10 years.

(8) The program has led to an ISIS telemetry network (distinct from NASA's telemetry network), which after 1972 has met most of the telemetry requirements of the ISIS program.

(9) Finally, the program has had an outstanding record in making the data available to the scientific community. The Alouette-ISIS program was the first satellite program to make extensive and well-documented contributions of data to the international data centers. Approximately 100 Alouette-ISIS data sets (Jackson and Horowitz,* 1986) are available at the National Space Science Data Center. The magnitude of these data holdings can be conveyed by pointing out that the one million Alouette 1 ionograms constitute only one data set. Because of its very early support of data center activities, the Alouette-ISIS Working Group also helped to develop some of the procedures and policies for submitting satellite data to the data centers. Data from the Alouette-ISIS program made available in this manner have been used by over 50 research groups and agencies.

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* J. E. Jackson and R. N. Horowitz, "Data Catalog Series for Space Science and Applications Flight Missions, Volume 3B, Descriptions of Data Sets from Low- and Medium-Altitude Scientific Spacecraft and Investigations," NSSDC/WDC-A-R&S 86-01, April 1986.

TABLE 5. RETIRED ALOUETTE/ISIS DATA ACQUISITION STATIONS (MARCH 1984)*

| STATION | CODE | NO. | LONG Deg | LONG Min | LAT Deg | LAT Min | START | END | AGENCY** |
|---|---|---|---|---|---|---|---|---|---|
| Ascension Island | ACN | 56 | 345 | 41 | -07 | 57 | | 18 Apr 80 | GSFC |
| Antofagasta, Chile | AG | | 239 | 43 | -23 | 37 | 29 Sept 62 | Jul 63 | GSFC |
| Santiago, Chile | AGO | 08 | 289 | 19 | -33 | 08 | Jul 63 | 18 Apr 80 | GSFC |
| Ahmedabad, India | AME | 57 | 072 | 31 | 23 | 01 | 28 Aug 65 | Mar 81 | PRL |
| Richland, Washington | BAT | 67 | 240 | 24 | 46 | 24 | 13 Nov 73 | 15 May 78 | BATT |
| Boulder, Colorado | BOUL | 46 | 254 | 52 | 40 | 05 | Dec 65 | 31 Mar 72 | NOAA |
| Blossom Point, Maryland | BPT | 01 | 282 | 30 | 38 | 25 | 29 Nov 65 | 01 Sep 66 | GSFC |
| Bretigny, France | BRET | 79 | 002 | 21 | 48 | 36 | 19 Jun 66 | 16 Dec 72 | CNES |
| Byrd Sta., Antarctica | BRDS | 51 | 240 | 30 | -80 | 00 | Mar 65 | 22 Feb 71 | STAN |
| Johannesburg, S. Africa | BUR | 16 | 027 | 42 | -25 | 52 | 29 Nov 65 | 31 Oct 75 | GSFC |
| Brazzaville, Congo | BZV | 97 | 015 | 15 | -04 | 11 | 19 Jun 66 | 01 Jun 74 | CNES |
| Las Palmas, Canary Is. | CNA | 93 | 344 | 34 | 27 | 50 | Nov 67 | 31 Dec 75 | CNES |
| College, Alaska | COL | 13 | 212 | 09 | 64 | 52 | 29 Sept 65 | 31 Oct 66 | GSFC |
| Darwin, Australia | DAR | 65 | 130 | 49 | -12 | 28 | 08 Jul 72 | 30 Dec 74 | IPSD |
| Greenbelt, Maryland | ETC | 24 | 283 | 09 | 39 | 00 | | 18 Apr 80 | GSFC |
| Fort Myers, Florida | FTMY | 03 | 278 | 08 | 26 | 32 | 29 Sept 62 | 09 Jul 72 | GSFC |
| East Grand Forks, Minn. | GRK | 14 | 262 | 59 | 48 | 01 | 29 Sept 62 | 01 Jul 66 | GSFC |
| Guam | GWM | 23 | 144 | 44 | 13 | 18 | 30 Jun 77 | 18 Apr 80 | GSFC |
| Kauai, Hawaii | HAW | 37 | 200 | 20 | 22 | 08 | Sept 75 | 31 Dec 77 | GSFC |
| Colomb Bechar, Algeria | HMG | 74 | 358 | 00 | 30 | 49 | 19 Jun 66 | 01 Jul 66 | CNES |
| South Point, Hawaii | HW | | 204 | 18 | 18 | 56 | 07 Nov 62 | 14 Jun 65 | GSFC |
| Kano, Nigeria | KNO | 53 | 008 | 31 | 11 | 58 | 29 Sept 64 | 18 Nov 66 | GSFC |
| Kourou, French Guyana | KRU | 92 | 307 | 92 | 05 | 15 | 03 Jan 72 | Nov 80 | CNES |
| Lauder, New Zealand | LAU | 60 | 169 | 41 | -45 | 02 | 02 Nov 71 | 28 Sep 80 | DSIR |
| Lima, Peru | LIMA | 06 | 282 | 50 | -11 | 46 | 29 Nov 65 | 02 Aug 69 | GSFC |
| Merritt Island, Florida | MIL | 71 | 279 | 18 | 28 | 30 | 01 Aug 73 | 31 Dec 77 | GSFC |
| St. Johns, Canada | NEWF | 12 | 307 | 16 | 47 | 44 | 29 Sept 62 | 09 Mar 70 | GSFC |
| Ouagadougou, Upper Volta | ODG | 96 | 358 | 50 | 12 | 41 | 19 Jun 66 | 31 Aug 76 | CNES |
| Woomera, Australia | OW | 18 | 136 | 52 | -31 | 23 | 29 Sept 62 | Oct 65 | GSFC |
| Prince Albert, Sask. | PA | | 254 | 04 | 53 | 13 | 29 Sept 62 | Aug 63 | CRC |
| Pretoria, S. Africa | PTA | 91 | 028 | 22 | -25 | 33 | 06 Mar 70 | 23 Feb 81 | CNES |
| Quito, Ecuador | QUI | 05 | 281 | 25 | -00 | 37 | 29 Sept 62 | 18 Apr 80 | GSFC |
| Chilton, England | RAL | 15 | 358 | 41 | 51 | 34 | 08 Apr 81 | 23 Dec 81 | RAL |
| Resolute Bay, Canada | RES | 43 | 265 | 07 | 74 | 41 | 29 Sept 62 | 14 Aug 79 | CRC |
| Rosman, North Carolina | ROS | | 277 | 07 | 35 | 12 | | | GSFC |
| Singapore | SNPO | 48 | 103 | 49 | 01 | 25 | 29 Sept 62 | 31 Jul 71 | RSRS |
| Falkland Islands | SOLA | 38 | 302 | 10 | -51 | 41 | 29 Sept 62 | 31 Dec 72 | RSRS |
| Thumba, India | THU | 82 | 076 | 52 | 08 | 32 | 04 Mar 72 | Dec 77 | RRL |
| Tromso, Norway | TRM | 69 | 018 | 56 | 69 | 39 | 16 Aug 66 | Feb 77 | NTNF |
| Winkfield, England | WNK | 15 | 359 | 18 | 51 | 26 | 29 Sept 62 | 31 Mar 81 | GSFC |

* The information in Table 5 was provided by J. David R. Boulding, Manager, Spacecraft Ground Control, CRC, Ottawa, Canada.

** The agency abbreviations are explained in a list following Table 6.

TABLE 6. DATA ACQUISITION STATIONS FOR ISIS SATELLITES AVAILABLE AS OF MARCH 1984*

| STATION | CODE | NO. | LONG Deg | LONG Min | LAT Deg | LAT Min | START | AGENCY** |
|---|---|---|---|---|---|---|---|---|
| Terre Adelie, Antarctica | ADL | 35 | 140 | 01 | -66 | 40 | 15 Jan 72 | LGE |
| Kerguelen Island | KER | 84 | 070 | 12 | -49 | 21 | 26 Mar 77 | CNES |
| Kashima, Japan | KSH | 70 | 140 | 39 | 35 | 57 | 15 Aug 66 | RRL |
| Ottawa, Canada | OTT | 50 | 284 | 07 | 45 | 21 | 29 Sept 62 | CRC |
| Orroral, Australia | ORR | 21 | 148 | 57 | -35 | 37 | 29 Nov 65 | GSFC |
| Sodankyla, Finland | SOD | 98 | 026 | 38 | 67 | 22 | 05 Dec 77 | GEFSO |
| Syowa, Antarctica | SYO | 80 | 039 | 35 | -69 | 00 | 05 Apr 76 | RRL |
| Fairbanks, Alaska | ULA | 19 | 212 | 29 | 64 | 58 | 29 Nov 66 | GSFC |
| England | UKZ | 17 | 358 | 07 | 51 | 37 | May 82 | |

* The information in Table 6 was provided by J. David R. Boulding, Manager, Spacecraft Ground Control, CRC, Ottawa, Canada.

** The agency abbreviations are explained below.

SPONSORING AGENCIES FOR CURRENT AND RETIRED STATIONS

BATT - Battelle Institute, USA

CNES - Centre National d'Etudes Spatiales, France

CRC - Communications Research Centre, Canada

DSIR - Department of Scientific and Industrial Research, New Zealand

GEFSO - Geophysical Observatory, Finland

GSFC - Goddard Space Flight Center, USA

IPSD - Ionospheric Prediction Service Division, Australia

LGE - Laboratoire de Geophysique Externe, France

NOAA - National Oceanic and Atmospheric Administration, USA

NTNF - Council for Scientific and Industrial Research, Norway

PRL - Physical Research Laboratory, India

RRL - Radio Research Laboratories, Japan

RSRS - Radio Space Research Station, England

STAN - Stanford University, USA

RAL - Rutherford and Appleton Laboratory, England

# Spacecraft and Experiment Characteristics with Literature References

***************************** ALOUETTE 1************************

SPACECRAFT COMMON NAME- ALOUETTE 1
ALTERNATE NAMES- 1962 BETA ALPHA 1, S 27
ALOUETTE-A, 00424
S 27A

NSSDC ID- 62-049A

LAUNCH DATE- 09/29/62 WEIGHT- 145.7 KG
LAUNCH SITE- VANDENBERG AFB, UNITED STATES
LAUNCH VEHICLE- THOR

SPONSORING COUNTRY/AGENCY

| | |
|---|---|
| CANADA | DRB-DRTE |
| UNITED STATES | NASA-OSSA |

INITIAL ORBIT PARAMETERS

| | |
|---|---|
| ORBIT TYPE- GEOCENTRIC | EPOCH DATE- 10/17/62 |
| ORBIT PERIOD- 105.5 MIN | INCLINATION- 80.5 DEG |
| PERIAPSIS- 996. KM ALT | APOAPSIS- 1032. KM ALT |

PERSONNEL

| | | |
|---|---|---|
| PM - J.E. | JACKSON | NASA-GSFC |
| PM - R.K. | BROWN(NLA) | DRB-DRTE |
| PS - J.E. | JACKSON | NASA-GSFC |
| PS - E.S. | WARREN(DECEASED) | DRB-DRTE |

BRIEF DESCRIPTION

Alouette 1 was a small ionospheric observatory instrumented with an ionospheric sounder, a VLF receiver, an energetic particle detector, and a cosmic noise experiment. Extended from the satellite shell were two dipole antennas (45.7- and 22.8-m long, respectively) which were shared by three of the experiments on the spacecraft. The satellite was spin-stabilized at about 1.4 rpm after antenna extension. After about 500 days, the spin slowed more than had been expected, to about 0.6 rpm when satellite spin-stabilization failed. It is believed that the satellite gradually progressed toward a gravity gradient stabilization with the longer antenna pointing earthward. Attitude information was deduced only from a single magnetometer and temperature measurements on the upper and lower heat shields. (Attitude determination could have been in error by as much as 10 deg.) There was no tape recorder, so data were available only from the vicinity of telemetry stations. Telemetry stations were located to provide primary data coverage near the 80 deg W meridian and in areas near Hawaii, Singapore, Australia, Europe, and Central Africa. Initially, data were recorded for about 6 h per day. In September 1972, spacecraft operations were terminated.

BIBLIOGRAPHY


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|---|---|---|---|---|---|---|---|---|---|
| 2 | 3 | 27 | 51 | 123 | 124 | 142 | 143 | 189 | 191 |
| 194 | 195 | 201 | 226 | 232 | 253 | 271 | 300 | 308 | 309 |
| 310 | 311 | 319 | 320 | 321 | 381 | 397 | 427 | 440 | 441 |
| 442 | 472 | 524 | 525 | 566 | 583 | 584 | 585 | 586 | 587 |
| 646 | 648 | 649 | 724 | 725 | 732 | 749 | 810 | 820 | 867 |
| 870 | 902 | 903 | 904 | 905 | 906 | 907 | 908 | 929 | 938 |


------- ALOUETTE 1, WARREN-------------------------------------

INVESTIGATION NAME- SWEEP-FREQUENCY SOUNDER

NSSDC ID- 62-049A-01 INVESTIGATIVE PROGRAM
CODE EE, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES AND RADIO PHYSICS

PERSONNEL

| | | |
|---|---|---|
| PI - E.S. | WARREN(DECEASED) | DOC-CRC |
| OI - J.H. | WHITTEKER | DOC-CRC |
| OI - J.E. | JACKSON | NASA-GSFC |
| OI - L. | COLIN | NASA-ARC |
| OI - J.W. | KING | RUTHERFORD APPLETON L. |
| OI - R.W. | KNECHT | NATL BUREAU OF STD |
| OI - G.L. | NELMS | DOC-CRC |

BRIEF DESCRIPTION

The purpose of the sweep frequency sounder was to conduct synoptic measurements of the electron density distribution in the ionosphere at altitudes between 300 and 1000 km. The instrumentation consisted of a radio transmitter/receiver that recorded the time delay between a transmitted and returned radio pulse. A continuum of frequencies between 0.5 and 12 MHz was sampled once every 18 s. Several delay times were usually observed for each frequency due to ground reflections, plasma resonances, birefringence of the ionosphere, nonvertical propagation, etc. Delay time was primarily a function of distance traversed by the signal, the electron density along the propagation path, and the mode of propagation. The standard data form was an ionogram (graph) showing time (virtual distance of signal reflection from the satellite) vs radio frequency. Two other common forms of data were prepared from the ionograms. They were (1) digital frequency data and/or virtual height values of characteristic ionospheric features and (2) computations of electron density profiles. Performance far exceeded expectations for the experiment. Initially, observations were recorded for about 6 h per day. The experiment provided data for 10 full years.

BIBLIOGRAPHY


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|---|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 4 | 7 | 9 | 11 | 15 | 17 | 18 | 25 |
| 26 | 29 | 30 | 41 | 42 | 43 | 44 | 45 | 46 | 47 |
| 48 | 49 | 50 | 51 | 64 | 67 | 70 | 71 | 76 | 78 |
| 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 90 | 91 |
| 94 | 95 | 109 | 113 | 117 | 119 | 120 | 121 | 122 | 125 |
| 126 | 127 | 135 | 144 | 161 | 163 | 166 | 167 | 169 | 172 |
| 183 | 184 | 185 | 187 | 189 | 190 | 191 | 192 | 193 | 195 |
| 197 | 202 | 203 | 204 | 208 | 215 | 217 | 218 | 219 | 222 |
| 223 | 225 | 226 | 227 | 228 | 229 | 238 | 240 | 241 | 242 |
| 243 | 244 | 245 | 246 | 247 | 249 | 250 | 252 | 254 | 255 |
| 256 | 257 | 258 | 264 | 265 | 266 | 269 | 270 | 274 | 275 |
| 276 | 277 | 278 | 279 | 280 | 281 | 282 | 283 | 284 | 285 |
| 286 | 287 | 288 | 289 | 290 | 291 | 292 | 293 | 294 | 301 |
| 303 | 304 | 305 | 306 | 316 | 318 | 322 | 327 | 331 | 332 |
| 333 | 334 | 340 | 347 | 348 | 351 | 357 | 360 | 361 | 368 |
| 372 | 377 | 396 | 398 | 400 | 401 | 418 | 427 | 429 | 430 |
| 435 | 436 | 437 | 438 | 439 | 442 | 443 | 444 | 459 | 461 |
| 462 | 463 | 473 | 474 | 476 | 477 | 478 | 479 | 480 | 481 |
| 482 | 483 | 484 | 485 | 486 | 487 | 488 | 489 | 490 | 491 |
| 492 | 493 | 494 | 495 | 496 | 497 | 499 | 500 | 512 | 515 |
| 517 | 520 | 521 | 527 | 528 | 529 | 530 | 531 | 536 | 540 |
| 541 | 543 | 544 | 546 | 547 | 548 | 549 | 550 | 551 | 552 |
| 553 | 562 | 564 | 565 | 588 | 596 | 597 | 598 | 599 | 601 |
| 635 | 636 | 638 | 640 | 641 | 645 | 654 | 655 | 656 | 657 |
| 658 | 659 | 661 | 663 | 665 | 667 | 668 | 670 | 677 | 679 |
| 688 | 693 | 694 | 695 | 696 | 698 | 700 | 701 | 705 | 706 |
| 707 | 708 | 709 | 711 | 712 | 713 | 724 | 731 | 732 | 739 |
| 742 | 743 | 744 | 745 | 746 | 747 | 750 | 751 | 757 | 758 |
| 759 | 761 | 779 | 791 | 793 | 794 | 806 | 807 | 808 | 811 |
| 812 | 813 | 817 | 820 | 827 | 841 | 842 | 844 | 845 | 848 |
| 849 | 851 | 852 | 853 | 854 | 855 | 856 | 857 | 858 | 860 |
| 862 | 863 | 867 | 868 | 869 | 870 | 871 | 872 | 873 | 874 |
| 875 | 876 | 877 | 878 | 879 | 880 | 885 | 886 | 888 | 889 |
| 893 | 899 | 900 | 912 | 913 | 914 | 924 | 925 | 926 | 927 |
| 932 | 933 | 934 | 935 | 936 | 941 | 965 | 967 | 968 | |


------- ALOUETTE 1, MCDIARMID------------------------------------

INVESTIGATION NAME- ENERGETIC PARTICLES DETECTORS

NSSDC ID- 62-049A-02 INVESTIGATIVE PROGRAM
CODE EE, SCIENCE

INVESTIGATION DISCIPLINE(S)
PARTICLES AND FIELDS

PERSONNEL

| | | |
|---|---|---|
| PI - I.B. | MCDIARMID | NATL RES COUNC OF CAN |

BRIEF DESCRIPTION

This experiment consisted of six detectors whose objectives were to determine the intensity structure of the lower portion of the outer Van Allen radiation belt at high latitudes and measure intensity changes associated with solar and geophysical phenomena, particularly auroras. The first, an Anton 302 Geiger counter, was in a shielded part of the package and was used only for omnidirectional measurements of protons and electrons with energies greater than 33 and 2.8 MeV, respectively. An Anton 223 Geiger counter, which pointed 10 deg off the spacecraft spin axis, responded directionally to electrons and protons with energies greater than 40 and 500 keV, respectively. A second Anton 223 Geiger counter, pointed parallel to the spacecraft spin axis and coupled to a magnetic broom, responded directionally to electrons and protons with energies greater than 250 and 500 keV. Omnidirectionally, both Geiger counters responded to electrons and protons with energies greater than 2.8 and 33 MeV, respectively. The fourth detector, a silicon junction, was collimated to look 10 deg off the spin axis. Directionally, it responded to protons and alpha particles in the energy ranges 1.3 to 7 and 4.3 to 28 MeV, respectively. Omnidirectionally, the silicon junction responded to protons in the energy range 55 to 60 MeV. The last two detectors, a Geiger telescope consisting of two trays of Philips 18509 Geiger counters and a plastic scintillator located between the two Geiger counter trays of the telescope, were pointed perpendicular to the spacecraft spin axis. These detectors had only directional responses to protons and alpha particles with energies greater than 100 and 400 MeV, respectively. This experiment performed well initially and was turned off on January 29, 1968, though still performing normally. No alpha particle data were obtained from this experiment.

BIBLIOGRAPHY


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|---|---|---|---|---|---|---|---|---|---|
| 11 | 63 | 137 | 153 | 191 | 205 | 324 | 328 | 329 | 339 |
| 372 | 379 | 383 | 442 | 456 | 457 | 458 | 460 | 539 | 605 |
| 606 | 607 | 608 | 609 | 610 | 611 | 617 | 618 | 619 | 654 |
| 732 | 782 | 883 | | | | | | | |


------- ALOUETTE 1, BELROSE-------------------------------------

INVESTIGATION NAME- VLF RECEIVER

NSSDC ID- 62-049A-03 INVESTIGATIVE PROGRAM
CODE EE, SCIENCE

INVESTIGATION DISCIPLINE(S)

IONOSPHERES AND RADIO PHYSICS

PERSONNEL
PI - J.S. BELROSE — DOC-CRC
OI - F.H. PALMER — DEFENCE RESEARCH ESTAB
OI - H.G. JAMES — DOC-CRC

BRIEF DESCRIPTION
The purpose of the VLF experiment was to investigate the propagation characteristics of natural and manmade VLF signals. This experiment was a wideband high-gain receiver with a passband from 0.4 to 10 kHz using only the longest (45.7 m) sounder antenna. The receiver output, which sensed the electric field component of the signal strength, was maintained constant by means of an AGC loop. The standard VLF data form was a sonogram (graph) showing signals as a function of time and frequency. Whistlers and radio noise of various origins were observed in this region of radio frequencies. Performance had been nominal since launch, except for interference from the sounder which had not prevented observation of useful data. The sounder operation was most frequent, but a small percentage of observations were VLF only or both VLF and sounder.

BIBLIOGRAPHY

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 11 | 60 | 61 | 62 | 63 | 65 | 69 | 70 | 71 | 89 |
| 138 | 139 | 140 | 141 | 145 | 175 | 176 | 177 | 178 | 179 |
| 191 | 193 | 226 | 325 | 341 | 342 | 344 | 345 | 346 | 442 |
| 538 | 569 | 633 | 719 | 725 | 726 | 731 | 732 | 809 | 812 |
| 818 | 850 | | | | | | | | |

------- ALOUETTE 1, HARTZ--------------------------------------

INVESTIGATION NAME- COSMIC RADIO NOISE

NSSDC ID- 62-049A-04 — INVESTIGATIVE PROGRAM
CODE EE, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES AND RADIO PHYSICS
ASTRONOMY

PERSONNEL
PI - T.R. HARTZ(RETIRED) — DOC-CRC

BRIEF DESCRIPTION
This experiment utilized the ionosonde receiver automatic gain control (AGC) voltage to measure the galactic and solar radio noise levels. The sweep-frequency receiver covered the range from 0.5 to 12 MHz in 18 s, but below 5 MHz the system response dropped off rapidly. The receiver had a noise figure of 15 dB, a bandwidth of 33 kHz, and a dynamic range of 50 dB. The antennas were two orthogonal dipoles, 45.7 and 22.8 m long, located orthogonal to the spacecraft spin axis. The experiment functioned satisfactorily, providing relatively good frequency resolution with relatively poor flux resolution.

BIBLIOGRAPHY

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|---|---|---|---|---|---|---|---|---|---|
| 11 | 67 | 134 | 191 | 226 | 326 | 368 | 369 | 370 | 371 |
| 373 | 374 | 378 | 442 | 459 | 732 | 893 | | | |

*************************** IE-A ******************************

SPACECRAFT COMMON NAME- IE-A
ALTERNATE NAMES- EXPLORER 20, S 48
TOPSI, 00870

NSSDC ID- 64-051A

LAUNCH DATE- 08/25/64 — WEIGHT- 44. KG
LAUNCH SITE- VANDENBERG AFB, UNITED STATES
LAUNCH VEHICLE- SCOUT

SPONSORING COUNTRY/AGENCY
UNITED STATES — NASA-OSSA

ORBIT PARAMETERS
ORBIT TYPE- GEOCENTRIC — EPOCH DATE- 12/12/65
ORBIT PERIOD- 104. MIN — INCLINATION- 79.9 DEG
PERIAPSIS- 864. KM ALT — APOAPSIS- 1025. KM ALT

PERSONNEL
PM - J.E. JACKSON — NASA-GSFC
PS - J.E. JACKSON — NASA-GSFC

BRIEF DESCRIPTION
Explorer 20 was designed to measure electron distribution, ion density and temperature, and to estimate cosmic noise levels between 2 and 7 MHz. The satellite was a small ionospheric observatory instrumented with a six-frequency ionospheric sounder and an ion probe. A cosmic noise experiment used the noise signal from the sounder receivers. The satellite consisted of a short cylinder terminated on either end by truncated cones. The ion probe, mounted on a short boom, extended from the upper cone. The six sounding antennas (3 dipoles) extended from the satellite equator. One pair of 18.28 m antennas formed the dipole used for the low frequencies, and the other two dipoles consisted of four 9.14 m antennas. The satellite was spin stabilized at 1.53 rpm just after antenna extension, with the spin axis initially very close to the orbit plane. At the end of 1 year, the spin had slowed to 0.45 rpm. Since there was no tape recorder, data were received only in the vicinity of telemetry stations. Telemetry stations were located to provide primary data coverage near 80 deg W plus areas near Hawaii, Singapore, England, Australia, and Africa. Data were recorded for periods of 1/2 h to over 4 h per day depending upon available power. Even though there were problems with telemetry and interference, the experiments operated satisfactorily for about 16 months. A large spacecraft plasma sheath prevented the ion probe data from being useful in spite of attempts to compensate. For this spacecraft, the 1-yr automatic satellite turnoff was disconnected just prior to launch. The satellite responses to command signals were not dependable after December 20, 1965, and the satellite transmitter, which was often spuriously turned on, did not respond to a turnoff command.

BIBLIOGRAPHY

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 5 | 171 | 201 | 271 | 362 | 428 | 440 | 441 | 442 | 511 |
| 513 | 514 | 792 | 903 | 907 | | | | | |

------- IE-A, KNECHT--------------------------------------

INVESTIGATION NAME- FIXED-FREQUENCY IONOSONDE

NSSDC ID- 64-051A-01 — INVESTIGATIVE PROGRAM
CODE EE/CO-OP, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES AND RADIO PHYSICS

PERSONNEL
PI - R.W. KNECHT — NATL BUREAU OF STD
OI - W. CALVERT — U OF IOWA
OI - T.E. VAN ZANDT — NOAA-ERL
OI - R.B. NORTON — NOAA-ERL
OI - J.M. WARNOCK — NOAA

BRIEF DESCRIPTION
The purpose of the fixed-frequency ionosonde was to investigate ionospheric electron density in the altitude range 300 to 1000 km. The experiment was most useful for the study of irregularities in the electron density distribution and for the investigation of fine structure in the plasma resonances. The fixed-frequency ionosonde was a radio transmitter-receiver that recorded the time delay between a transmitted and a returned radio pulse. Six specific frequencies from 1.5 to 7.22 MHz were sampled in sequence once every 0.105 second. Several delay times were often observed for each frequency due to plasma resonances, birefringence of the ionosphere, nonvertical propagation, etc. Delay time was primarily a function of distance traversed by the signal, electron density along the signal path, and the mode of propagation. A total of 1450 h of data was acquired. Most of these data were of adequate quality to prepare ionograms. Since only time is noted on each ionogram, satellite position and other related information must be obtained from world maps.

BIBLIOGRAPHY

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|---|---|---|---|---|---|---|---|---|---|
| 119 | 159 | 160 | 161 | 163 | 168 | 169 | 170 | 171 | 173 |
| 180 | 217 | 246 | 266 | 295 | 396 | 442 | 444 | 465 | 466 |
| 480 | 498 | 511 | 513 | 514 | 533 | 535 | 554 | 563 | 596 |
| 597 | 598 | 599 | 600 | 601 | 602 | 663 | 665 | 742 | 792 |
| 812 | 866 | 873 | 896 | 897 | 922 | | | | |

------- IE-A, BOYD--------------------------------------

INVESTIGATION NAME- SPHERICAL ION-MASS SPECTROMETER

NSSDC ID- 64-051A-02 — INVESTIGATIVE PROGRAM
CODE EE/CO-OP, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES
AERONOMY

PERSONNEL
PI - R.L.F.BOYD(RETIRED) — U COLLEGE LONDON
OI - A.P. WILLMORE — U OF BIRMINGHAM

BRIEF DESCRIPTION
The ion probe on Explorer 20 was a spherical retardin potential instrument from which ion mass spectra and io temperatures could be determined. It consisted of a spherica inner electrode, 9 cm in diam, surrounded by a spherical gridded (0.5 mm holes), nickel foil covering, 10 cm in diam an 0.1 mm thick. A negative charge was maintained in the grid t remove electron effects. The more massive ions passed throug the grid to form an ion current dependent upon the voltag condition of the inner electrode. A slow-sweeping sawtoot potential from about -2 to +10 volts (with two low-voltage 0.5- and 3.2-kHz sinewave forms impressed upon it) provided profile of voltage versus ion current. The change in slope o the voltage versus ion current profile, gives the energ distribution profile, which, for thermal ions, is a function o ion mass and satellite velocity. Thermal ion velocitie broaden the mass peaks somewhat and thereby degrade mas resolution slightly, but this broadening effect was used t determine the ion temperature. Analysis of current variatior resulting from the two sinewave forms on the sweep voltage provided the required slope change data for analysis of tr profiles. The probe was mounted at the positive end of tr spin (Z) axis on a short tubular support. With the nomina spin axis, perpendicular to the orbit plane, this arrangemer eliminated spin modulation of the observations. Although th experiment functioned properly, the occurrence of a lar

ORIGINAL PAGE IS
OF POOR QUALITY

plasma sheath about the spacecraft, prevented acquisition of scientifically useful data.

BIBLIOGRAPHY

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------- IE-A, STONE-------------------------------------------

INVESTIGATION NAME- COSMIC NOISE

NSSDC ID- 64-051A-03

INVESTIGATIVE PROGRAM
CODE EE/CO-OP, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES AND RADIO PHYSICS
ASTRONOMY

PERSONNEL

| | | |
|---|---|---|
| PI - R.G. | STONE | NASA-GSFC |

BRIEF DESCRIPTION

The cosmic noise experiment utilized the noise signal from the sounder receiver to investigate cosmic noise in the 1.5- to 7.2-MHz frequency range. The measurements were in rough agreement with previous observations of cosmic noise. The receiver calibration, however, was not sufficiently accurate to yield new scientific results.

BIBLIOGRAPHY
NO REFERENCES

************************** ALOUETTE 2**********************

SPACECRAFT COMMON NAME- ALOUETTE 2
ALTERNATE NAMES- ALOUETTE-B, S 27B
ISIS-X, 01804

NSSDC ID- 65-098A

LAUNCH DATE- 11/29/65 WEIGHT- 146. KG
LAUNCH SITE- VANDENBERG AFB, UNITED STATES
LAUNCH VEHICLE- THOR

SPONSORING COUNTRY/AGENCY

| | |
|---|---|
| CANADA | DRB-DRTE |
| UNITED STATES | NASA-OSSA |

INITIAL ORBIT PARAMETERS

| | |
|---|---|
| ORBIT TYPE- GEOCENTRIC | EPOCH DATE- 11/30/65 |
| ORBIT PERIOD- 121.4 MIN | INCLINATION- 79.8 DEG |
| PERIAPSIS- 505. KM ALT | APOAPSIS- 2987. KM ALT |

PERSONNEL

| | | |
|---|---|---|
| PM - E.D. | NELSEN(NLA) | NASA-GSFC |
| PM - C.D. | FLORIDA(DECEASED) | DRB-DRTE |
| PS - I. | PAGHIS(RETIRED) | DRB-DRTE |
| PS - J.E. | JACKSON | NASA-GSFC |

BRIEF DESCRIPTION

Alouette 2 was a small ionospheric observatory instrumented with a sweep-frequency ionospheric sounder, a VLF receiver, an energetic particle experiment, a cosmic noise experiment, and an electrostatic probe. The spacecraft used two long dipole antennas (73 m and 22.8 m, respectively) for the sounder, VLF, and cosmic noise experiments. The satellite was spin-stabilized at about 2.25 rpm after antenna deployment. End plates on the 73 m antenna corrected the rapid despin that had occurred on Alouette 1, and which was believed to result from thermal distortion of the antenna and from radiation pressure. There was no tape recorder, so that data were available only when the spacecraft was in line of sight of telemetry stations. Telemetry stations were located so that primary data coverage was near the 80 deg W meridan plus areas near Hawaii, Singapore, Australia, England, India, Norway, and Central Africa. Initially data were recorded about 8 h per day. Degradation of the power supply system had, by June 1975, reduced the operating time to about 1/2 h per day. Routine operations were terminated in July 1975. The spacecraft was successfully reactivated on November 28 and 29, 1975, in order to obtain data on its 10th annniversary.

BIBLIOGRAPHY

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|---|---|---|---|---|---|---|---|---|---|
| 27 | 96 | 124 | 196 | 271 | 308 | 309 | 310 | 311 | 320 |
| 321 | 381 | 442 | 472 | 586 | 810 | 812 | 902 | 903 | 904 |
| 905 | 906 | 907 | 908 | 929 | | | | | |

------- ALOUETTE 2, WARREN------------------------------------

INVESTIGATION NAME- SWEEP-FREQUENCY SOUNDER

NSSDC ID- 65-098A-01

INVESTIGATIVE PROGRAM
CODE EE, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES AND RADIO PHYSICS

PERSONNEL

| | | |
|---|---|---|
| PI - E.S. | WARREN(DECEASED) | DOC-CRC |
| OI - J.H. | WHITTEKER | DOC-CRC |
| OI - J.E. | JACKSON | NASA-GSFC |
| OI - J.W. | KING | RUTHERFORD APPLETON L. |
| OI - L. | COLIN | NASA-ARC |
| OI - J. | TURNER | IONOSPHERIC PRED SERV |
| OI - C. | TAIEB | CNET |
| OI - O. | HOLT | AURORAL OBS |
| OI - G.L. | NELMS | DOC-CRC |
| OI - Y. | OGATA | RADIO RESEARCH LAB |
| OI - R. | RAGHAVARAO | PHYSICAL RESEARCH LAB |
| OI - G.E.K. | LOCKWOOD | DOC-CRC |

BRIEF DESCRIPTION

The purpose of the sweep-frequency sounder experiment was to extend the Alouette 1 measurements to higher altitudes (3000 km) and to a different period of the solar cycle. The Alouette 2 sounder was also designed to provide greatly improved observations of plasma resonances. The sweep-frequency ionosonde was a radio transmitter/receiver that recorded the time delay between a transmitted and returned radio frequency pulse. A continuum of frequencies between 0.12 and 14.5 MHz were sampled once every 32 s. A multiplicity of delay times was usually observed due to birefringence of the ionosphere, nonvertical propagation, ground echoes, plasma resonances, etc. Delay time was primarily a function of distance traversed by the signal, electron density along the propagation path, and mode of propagation. The standard data form is an ionogram (graph) showing delay time (virtual distance of signal reflection from the satellite) versus frequency. Two other common forms of data were prepared from the ionograms. They are digital frequency and/or virtual height values of characteristic ionospheric features and computations of electron density profiles.

BIBLIOGRAPHY

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|---|---|---|---|---|---|---|---|---|---|
| 6 | 8 | 10 | 12 | 13 | 14 | 28 | 49 | 52 | 57 |
| 58 | 59 | 65 | 67 | 74 | 75 | 76 | 90 | 92 | 93 |
| 94 | 95 | 96 | 97 | 99 | 100 | 104 | 107 | 108 | 109 |
| 117 | 118 | 122 | 127 | 161 | 162 | 163 | 169 | 170 | 184 |
| 186 | 193 | 197 | 199 | 200 | 207 | 216 | 217 | 218 | 219 |
| 220 | 221 | 235 | 237 | 239 | 240 | 246 | 250 | 259 | 260 |
| 261 | 266 | 296 | 297 | 305 | 306 | 307 | 316 | 317 | 318 |
| 322 | 323 | 327 | 335 | 336 | 349 | 350 | 351 | 357 | 358 |
| 360 | 361 | 365 | 377 | 380 | 384 | 398 | 399 | 404 | 409 |
| 412 | 413 | 416 | 429 | 430 | 436 | 437 | 438 | 439 | 442 |
| 444 | 459 | 462 | 467 | 479 | 480 | 503 | 517 | 529 | 541 |
| 545 | 546 | 547 | 570 | 572 | 589 | 590 | 591 | 592 | 593 |
| 596 | 597 | 598 | 601 | 603 | 659 | 660 | 661 | 663 | 664 |
| 665 | 666 | 668 | 671 | 672 | 673 | 691 | 697 | 698 | 699 |
| 702 | 703 | 704 | 706 | 707 | 710 | 717 | 727 | 728 | 729 |
| 730 | 735 | 736 | 738 | 751 | 766 | 767 | 768 | 769 | 770 |
| 771 | 772 | 773 | 780 | 781 | 805 | 813 | 815 | 816 | 843 |
| 847 | 862 | 864 | 866 | 873 | 884 | 900 | 917 | 922 | 928 |
| 930 | 937 | 945 | 962 | 968 | | | | | |

------- ALOUETTE 2, BELROSE-----------------------------------

INVESTIGATION NAME- VLF RECEIVER

NSSDC ID- 65-098A-02

INVESTIGATIVE PROGRAM
CODE EE, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES AND RADIO PHYSICS

PERSONNEL

| | | |
|---|---|---|
| PI - J.S. | BELROSE | DOC-CRC |
| OI - F.H. | PALMER | DEFENCE RESEARCH ESTAB |
| OI - H.G. | JAMES | DOC-CRC |

BRIEF DESCRIPTION

The purpose of the VLF experiment was to investigate the VLF radio spectrum for whistlers, chorus, hiss, and resonance effects. The VLF experiment was a wideband high-gain receiver with a passband from 0.05 to 30 kHz that used the long sounder antenna. The instrument was a considerably improved version of the Alouette 1 receiver. The standard VLF data form was a sonogram (graph) that showed signal as a function of time and frequency. Whistlers, ionospheric noise, VLF noise, etc. were observed in this very low region of the radio frequency spectrum.

BIBLIOGRAPHY

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|---|---|---|---|---|---|---|---|---|---|
| 22 | 59 | 60 | 61 | 62 | 65 | 68 | 72 | 73 | 175 |
| 179 | 193 | 198 | 233 | 375 | 382 | 414 | 415 | 421 | 442 |
| 538 | 555 | 569 | 570 | 634 | 699 | 716 | 717 | 809 | |

------- ALOUETTE 2, HARTZ-------------------------------------

INVESTIGATION NAME- COSMIC RADIO NOISE

NSSDC ID- 65-098A-03

INVESTIGATIVE PROGRAM
CODE EE, SCIENCE

INVESTIGATION DISCIPLINE(S)
ASTRONOMY
IONOSPHERES AND RADIO PHYSICS

PERSONNEL
PI - T.R. HARTZ(RETIRED) DOC-CRC

BRIEF DESCRIPTION
This experiment used the ionosonde receiver automatic gain control (AGC) voltage to measure background radio noise from the ionosphere, galaxy, and sun. The antennas were dipoles 23 and 73 m long. The receiver swept the range 0.1 to 15 MHz every 32 s. The receiver bandwidth was 40 kHz, and the dynamic range was 80 dB. The receiver sensitivity permitted galactic radio emission observations at frequencies greater than 0.6 MHz. The experiment functioned satisfactorily, providing good frequency resolution with relatively poor flux resolution.

BIBLIOGRAPHY
67 73 175 326 358 359 373 374 375 376
380 699

------- ALOUETTE 2, MCDIARMID-------------------------------

INVESTIGATION NAME- ENERGETIC PARTICLE DETECTORS

NSSDC ID- 65-098A-04 INVESTIGATIVE PROGRAM
CODE EE, SCIENCE

INVESTIGATION DISCIPLINE(S)
PARTICLES AND FIELDS

PERSONNEL
PI - I.B. MCDIARMID NATL RES COUNC OF CAN

BRIEF DESCRIPTION
The purpose of the energetic particle experiment was to investigate the Van Allen radiation belt at high latitudes. The Alouette 2 energetic particle experiment was composed of seven detectors. Four of these were Geiger-Mueller (GM) tubes. The first responded to electrons greater than 3.9 MeV and protons greater than 40 MeV. The second had a magnetic broom and responded to electrons greater than 250 keV and protons greater than 500 keV. The third responded to electrons greater than 40 keV and protons greater than 500 keV. These three GM tubes were perpendicular to the spin axis. The fourth GM tube was 10 deg from the spin axis and responded to electrons greater than 40 keV and protons greater than 500 keV. The fifth detector was a silicon junction that detected protons and alpha particles with minimum energies of 1 and 5 MeV, respectively, and maximum energies of 8 and 24 MeV, respectively. The sixth detector was a Geiger telescope that detected protons greater than 100 MeV. The seventh detector was a plastic scintillator that determined the proton spectra in the energy range from 100 to 600 MeV. Particles associated with auroral and solar events were studied. No alpha particle data were obtained from this experiment.

BIBLIOGRAPHY
155 298 299 376 398 424 611 612 613 614
615 620 621 622 623 624 699 883 945

------- ALOUETTE 2, BRACE-------------------------------

INVESTIGATION NAME- CYLINDRICAL ELECTROSTATIC PROBES

NSSDC ID- 65-098A-05 INVESTIGATIVE PROGRAM
CODE EE, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES
AERONOMY

PERSONNEL
PI - L.H. BRACE NASA-GSFC

BRIEF DESCRIPTION
Two cylindrical electrostatic probes were used to measure local electron temperature and density at the satellite. The main purpose of this experiment, however, was to determine the feasibility of placing direct measurements on a spacecraft equipped with the long antennas required for topside sounding. The sensors were operated as Langmuir probes and consisted each of a collector electrode extending from the central axis of a cylindrical guard ring. The guard ring extended 23 cm from the spacecraft and the collector electrode extended 46 cm. The two sensors were mounted on opposite sides of the lower portion of the satellite and both extended downward at an angle of 45 deg to the spacecraft spin axis, which was oriented in a northward direction in the orbital plane. The sensors were operated sequentially. NSSDC has all the useful data that exist from this investigation.

BIBLIOGRAPHY
77 94 96 128 131 174 214 259 260 261
302 365 398 399 571 595 699 707 730 764
780 781 945

**************************** DME-A ****************************

SPACECRAFT COMMON NAME- DME-A
ALTERNATE NAMES- EXPLORER 31, ISIS-X
01806, S 30A

NSSDC ID- 65-098B

LAUNCH DATE- 11/29/65 WEIGHT- 99.0 KG
LAUNCH SITE- VANDENBERG AFB, UNITED STATES
LAUNCH VEHICLE- THOR

SPONSORING COUNTRY/AGENCY
UNITED STATES NASA-OSSA

INITIAL ORBIT PARAMETERS
ORBIT TYPE- GEOCENTRIC EPOCH DATE- 11/30/65
ORBIT PERIOD- 121.4 MIN INCLINATION- 79.8 DEG
PERIAPSIS- 505. KM ALT APOAPSIS- 2978. KM ALT

PERSONNEL
PM - E.D. NELSEN(NLA) NASA-GSFC
PS - J.E. JACKSON NASA-GSFC

BRIEF DESCRIPTION
Explorer 31 was a small ionospheric observatory instrumented to make direct measurements of selected ionospheric parameters at the spacecraft. It carried seven experiments: a thermal ion experiment, a thermal electron experiment, an electrostatic probe, an electron temperature probe, a spherical mass spectrometer, an energetic electron current monitor, and a magnetic ion-mass spectrometer. Since the spacecraft had no tape recorder, data could be observed at the spacecraft only when the spacecraft was in sight of the telemetry station and when commanded on. Experiments were operated either simultaneously or sequentially, as desired. The satellite was spin-stabilized with the spin axis perpendicular to the orbit plane. The spin rate and spin axis were controlled by an onboard magnetic torquing system. The attitude and spin rate information were observed by a sun sensor and a three-axis magnetometer. Satellite performance was satisfactory except for a partial power failure in May 1966, which reduced data acquisition time to about half the nominal amount. Some difficulties were encountered in obtaining attitude information that was necessary for the reduction of the experiment observations. On July 1, 1969, the satellite data observations were terminated with five of the seven experiments operating. Responsibility for standby monitoring of the satellite was given to the ESSA telemetry station at Boulder, Colorado, on July 8, 1969. During this standby operation, experiment data were collected only once on October 1, 1969, for 9 min from the electrostatic probe for use in studying a red arc event. On January 15, 1971, no response was received from a variety of satellite commands, and the satellite was abandoned.

BIBLIOGRAPHY
122 310 442

------- DME-A, DONLEY-------------------------------

INVESTIGATION NAME- THERMAL ION PROBE

NSSDC ID- 65-098B-01 INVESTIGATIVE PROGRAM
CODE EE, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES
AERONOMY

PERSONNEL
PI - J.L. DONLEY NASA-GSFC

BRIEF DESCRIPTION
The purpose of the thermal ion probe experiment was to measure ion density, temperature, and composition at the satellite. The sensor consisted of a planar ion trap with three circular mesh grids and a collector. With the innermost suppressor grid maintained at -15 V to exclude electrons and the middle retarding grid swept from zero to 6.3 V, the resulting current-voltage curve due to ion current was interpreted to obtain ion temperature, ion composition, and density. Determination of these parameters was made by curve fitting, assuming various models of ion parameters and assuming that the model with the least rms residual was correct. The associated electronics were shared with experiment 65-098B-06. Further details are given in J. L. Donley, "The thermal ion and electron trap experiments on the Explorer XXXI satellite," Proc. IEEE, v. 57, n. 6, pp. 1061-1067, June 1969. NSSDC has all the useful data that exist from this investigation.

BIBLIOGRAPHY
122 188 220 236 237 330 578 653 774 775
798 799 803 819

------- DME-A, BRACE-------------------------------

INVESTIGATION NAME- CYLINDRICAL ELECTROSTATIC PROBES

NSSDC ID- 65-098B-02 INVESTIGATIVE PROGRAM
CODE EE, SCIENCE

INVESTIGATION DISCIPLINE(S)
AERONOMY
IONOSPHERES

ORIGINAL PAGE IS
OF POOR QUALITY

PERSONNEL
PI - L.H. BRACE NASA-GSFC

BRIEF DESCRIPTION

The cylindrical electrostatic probes were used to measure electron temperature and density in the ionosphere. Each sensor was basically a Langmuir probe consisting of a collector electrode extending from the central axis of a cylindrical guard ring. The guard rings extended 23 cm from the spacecraft and the collector electrode extended 46 cm. The two sensors were mounted on opposite sides of the spacecraft, and were perpendicular to the spin axis and in the orbit plane. Data sets are no longer available from this experiment.

BIBLIOGRAPHY

57 122 128 131 174 220 237 302 365 595
642 798 799

------- DME-A, WILLMORE------------------------------------------

INVESTIGATION NAME- ELECTRON TEMPERATURE

NSSDC ID- 65-098B-03 INVESTIGATIVE PROGRAM
CODE EE, SCIENCE

INVESTIGATION DISCIPLINE(S)

PERSONNEL
PI - A.P. WILLMORE U OF BIRMINGHAM

BRIEF DESCRIPTION

The purpose of the electron temperature probe was to measure the energy distribution of ionospheric electrons. From these measurements electron temperature and density could be derived. The sensor was a disk, 2 cm in diameter, mounted flush with the satellite surface. The probe current-voltage characteristics were investigated by means of the same modulation technique that was used in the spherical ion-mass spectrometer. (See description for 65-098B-04.)

BIBLIOGRAPHY

237 797 800 801 802 847 865 892 950 961
962 963

------- DME-A, WILLMORE------------------------------------------

INVESTIGATION NAME- ION MASS SPECTROMETER

NSSDC ID- 65-098B-04 INVESTIGATIVE PROGRAM
CODE EE, SCIENCE

INVESTIGATION DISCIPLINE(S)

PERSONNEL
PI - A.P. WILLMORE U OF BIRMINGHAM

BRIEF DESCRIPTION

The spherical ion mass spectrometer probe was used to investigate the composition of positive ions at altitudes between 500 and 3000 km. The instrument consisted of a 9 cm diameter ion collector, circumscribed by a 10 cm diameter nickel grid that was approximately 40% transparent. The grid had a 6-V bias to prevent electrons from reaching the collector. The probe rested on top of a 32-cm-long rod mounted along the satellite spin axis. In addition to the principal bias-potential sweep, two small ac potentials were applied to the collector. The amplitude and depth of modulation of the resulting carrier current were then measured as a function of probe potential. This "retarding potential" ion spectrometer had low resolution. Hydrogen, with a mass-to-charge ratio (M/Q) of 1, was readily distinguished from atomic oxygen ions (M/Q = 16). However, atomic nitrogen ions (M/Q = 14) could not be distinguished from atomic oxygen ions. The signal current to the probe varied inversely with ionic mass, and consequently, the instrument was less sensitive to heavy masses. When the concentration of atomic oxygen ions was significantly greater than 300 ions per cc, accurate temperature measurements could be made for the atomic oxygen ions. Further details of the experiment can be found in G. L. Wrenn, "The Langmuir probe and spherical ion probe experiments aboard Explorer 31," Proc. IEEE, v. 45, n. 6, p. 1072, 1969.

BIBLIOGRAPHY

122 237 797 798 799 800 802 865 950 962

------- DME-A, HOFFMAN------------------------------------------

INVESTIGATION NAME- MAGNETIC ION-MASS SPECTROMETER

NSSDC ID- 65-098B-05 INVESTIGATIVE PROGRAM
CODE EE, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES
AERONOMY

PERSONNEL
PI - J.H. HOFFMAN U OF TEXAS, DALLAS

BRIEF DESCRIPTION

A magnetic sector field mass spectrometer was used to measure the abundances of the ionospheric positive ion species in the mass range 1 to 20 atomic mass units. The mass range was swept every 3 s by an exponentially decreasing accelerating voltage, which varied from -4000 to -150 volts. The ions were separated according to mass-to-charge ratio in the magnetic analyzer section of the spectrometer. A particular ion species, depending on the accelerating voltage, was then passed through the analyzer into an electron multiplier. The output ion current from the multiplier was measured by a logarithmic electrometer amplifier and converted to a voltage. The experiment operated normally and yielded useful data from launch on November 29, 1965, until about April 1967. Then low battery voltage resulted in a voltage regulator problem. The experiment provided useful data only intermittently after that, and it failed in March 1968. NSSDC has all the useful data that exist from this investigation.

BIBLIOGRAPHY

53 54 55 56 77 122 220 237 365 402
403 404 405 409 442 595 737

------- DME-A, DONLEY------------------------------------------

INVESTIGATION NAME- THERMAL ELECTRON PROBE

NSSDC ID- 65-098B-06 INVESTIGATIVE PROGRAM
CODE EE, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES
AERONOMY

PERSONNEL
PI - J.L. DONLEY NASA-GSFC

BRIEF DESCRIPTION

The purpose of the thermal electron probe experiment was to measure the electron density and temperature at the satellite. The instrumentation was a modified Langmuir probe in which unwanted ion and photo-current components were eliminated through the use of a grid with appropriate bias. The grid was mounted flush with the satellite surface and it received a sweep voltage of from -5 to +4 V. The collector was biased at +25 V. From the measured current-voltage data the electron density could be obtained with an accuracy of about 20%. The electron temperature could normally be obtained with an accuracy of about 150 deg K, but a computer curve-fitting analysis improved the accuracy to about 10 deg K. The associated electronics were shared with experiment 65-098B-01. Further details can be found in J. L. Donley, "The thermal ion and electron trap experiments on the Explorer XXXI satellite," Proc. IEEE, v. 57, n. 6, pp. 1061-1067, June 1969. NSSDC has all the useful data that exist from this investigation.

BIBLIOGRAPHY

122 188 235 236 237 330 578 579 595 653
692 774 775 798 799 803 804 892

------- DME-A, MAIER------------------------------------------

INVESTIGATION NAME- ENERGETIC ELECTRON CURRENT MONITOR

NSSDC ID- 65-098B-07 INVESTIGATIVE PROGRAM
CODE EE, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES
AERONOMY

PERSONNEL
PI - E.J. MAIER NASA-GSFC

BRIEF DESCRIPTION

The purpose of this experiment was to measure the electron energy spectrum in the suprathermal energy range of 0.2 to 2000 eV. Two three-grid retarding potential analyzers were used, one providing analog data in the 0.2 to 200 eV range and the other providing digital data in the 0.2 to 2000 eV range. The two analyzers had separate power supplies and associated electronics. The instrumentation for the digital measurement included an electron multiplier and a digital pulse counting system. Because of moisture contamination of the detector in the launch tower prior to launch, the gain of the electron multiplier was so degraded that no geophysical measurements could be obtained. The instrumentation for the analog measurement included a range-changing electrometer. The analog data were plots of the measured current-voltage function. The analog experiment yielded excellent data for 4 months, after which the experiment deteriorated because of radiation damage to its circuitry. Further details of the analog and digital instruments are presented in E. J. R. Maier, "Explorer XXXI total current monitor experiments," Proc. IEEE, v. 57, n. 6, pp. 1068-1071, June 1969. NSSDC has all the useful data that exist from this investigation.

BIBLIOGRAPHY

188 235 576 577 579 692 774 775 776

***************************** ISIS 1*****************************

SPACECRAFT COMMON NAME- ISIS 1
ALTERNATE NAMES- ISIS-A, 03669

NSSDC ID- 69-009A

LAUNCH DATE- 01/30/69 WEIGHT- 241. KG
LAUNCH SITE- VANDENBERG AFB, UNITED STATES
LAUNCH VEHICLE- DELTA

SPONSORING COUNTRY/AGENCY

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|---|---|
| CANADA | DRB-DRTE |
| UNITED STATES | NASA-OSSA |
| JAPAN | RRL |

INITIAL ORBIT PARAMETERS

| | |
|---|---|
| ORBIT TYPE- GEOCENTRIC | EPOCH DATE- 02/04/69 |
| ORBIT PERIOD- 128.42 MIN | INCLINATION- 88.42 DEG |
| PERIAPSIS- 578. KM ALT | APOAPSIS- 3526. KM ALT |

PERSONNEL

| | | |
|---|---|---|
| PM - L.H. | BRACE | NASA-GSFC |
| PM - C.D. | FLORIDA(DECEASED) | DRB-DRTE |
| PS - L.H. | BRACE | NASA-GSFC |
| PS - I. | PAGHIS(RETIRED) | DRB-DRTE |
| PS - J.E. | JACKSON | NASA-GSFC |

BRIEF DESCRIPTION

ISIS 1 was an ionospheric observatory instrumented with sweep- and fixed-frequency ionosondes, a VLF receiver, energetic and soft particle detectors, an ion mass spectrometer, an electrostatic probe, an electrostatic analyzer, a beacon transmitter, and a cosmic noise experiment. The sounder used two dipole antennas (73 and 18.7 m long). The satellite was spin-stabilized at about 2.9 rpm after antenna deployment. Some control was exercised over the spin rate and attitude by using magnetically induced torques to change the spin rate and to precess the spin axis. A tape recorder with 1-h capacity was included on the satellite. The satellite could be programmed to take recorded observations for four different time periods for each full recording period. The recorder data were dumped only at Ottawa. For non-tape-recorded observations, data for the satellite and subsatellite regions could be acquired and telemetered when the spacecraft was in the line of sight of telemetry stations. The selected telemetry stations were in areas that provided primary data coverage near the 80-deg-W meridian and in areas near Hawaii, Singapore, Australia, England, Norway, India, Japan, Antarctica, New Zealand, and Central Africa. NASA support of the ISIS project was terminated on October 1, 1979. A significant amount of experimental data, however, was acquired after this date by the Canadian project team. ISIS 1 operations were terminated in Canada on March 9, 1984. The Radio Research Laboratories (Tokyo, Japan) then requested and received permission to reactivate ISIS 1. Regular ISIS 1 operations were started from Kashima, Japan, in early August 1984.

BIBLIOGRAPHY

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|---|---|---|---|---|---|---|---|---|---|
| 16 | 27 | 196 | 272 | 308 | 309 | 310 | 311 | 337 | 381 |
| 446 | 526 | 537 | 567 | 568 | 647 | 650 | 760 | 778 | 822 |
| 904 | 905 | 906 | 909 | 910 | 911 | 944 | 969 | | |

------- ISIS 1, NELMS-----------------------------------------

INVESTIGATION NAME- SWEEP-FREQUENCY SOUNDER

NSSDC ID- 69-009A-01 INVESTIGATIVE PROGRAM
CODE EE/CO-OP, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES AND RADIO PHYSICS

PERSONNEL

| | | |
|---|---|---|
| PI - G.L. | NELMS | DOC-CRC |
| OI - J.E. | JACKSON | NASA-GSFC |
| OI - J.H. | WHITTEKER | DOC-CRC |
| OI - J. | TURNER | IONOSPHERIC PRED SERV |
| OI - M. | SYLVAIN | LGE |
| OI - O. | HOLT | AURORAL OBS |
| OI - Y. | OGATA | RADIO RESEARCH LAB |
| OI - R. | RAGHAVARAO | PHYSICAL RESEARCH LAB |
| OI - R.B. | NORTON | NOAA-ERL |
| OI - K.L. | CHAN | NASA-ARC |
| OI - R.S. | UNWIN | DEPT OF SCI+INDUST RES |

BRIEF DESCRIPTION

The purpose of this experiment was to investigate the ionospheric electron density in the altitude range 300 to 3500 km for a full solar cycle (by combining the ISIS 1 measurements with the Alouette 2 data). Another important function of the sounder was to provide correlative data for the other ISIS 1 experiments, particularly those measuring ionospheric parameters. The ISIS 1 ionosonde was basically a radio transmitter/receiver that recorded the time delay between a transmitted and a returned radio frequency pulse. A continuum of frequencies between 0.1 and 20 MHz was sampled once every 19 or 29 s, and one of six selected frequencies was also used for a period of 3 to 5 s during this 19- or 29-s period. In addition to the sweep- and fixed-frequency modes of operation, a mixed mode was possible where the transmitter frequency was fixed at 0.82 MHz while the receiver swept. Several virtual-height (delay-time) traces were normally observed due to ground reflections, plasma resonances, birefringence of the ionosphere, nonvertical propagation, etc. Virtual height at a given frequency was primarily a function of distance traversed by the signal, electron density along the propagation path, and mode of propagation. The standard data format was an ionogram showing virtual height as a function of frequency.

BIBLIOGRAPHY

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|---|---|---|---|---|---|---|---|---|---|
| 23 | 97 | 98 | 100 | 101 | 102 | 103 | 105 | 106 | 110 |
| 111 | 112 | 127 | 135 | 148 | 164 | 165 | 221 | 246 | 262 |
| 263 | 266 | 267 | 305 | 306 | 318 | 322 | 343 | 377 | 416 |
| 426 | 444 | 445 | 448 | 449 | 450 | 451 | 452 | 453 | 480 |
| 503 | 517 | 600 | 601 | 603 | 662 | 663 | 665 | 669 | 673 |
| 676 | 728 | 751 | 777 | 781 | 795 | 815 | 816 | 827 | 887 |
| 898 | 916 | 917 | 918 | 923 | 940 | 942 | 944 | 945 | 946 |

------- ISIS 1, CALVERT-----------------------------------------

INVESTIGATION NAME- FIXED-FREQUENCY SOUNDER

NSSDC ID- 69-009A-02 INVESTIGATIVE PROGRAM
CODE EE/CO-OP, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES AND RADIO PHYSICS

PERSONNEL

| | | |
|---|---|---|
| PI - W. | CALVERT | U OF IOWA |
| OI - R.B. | NORTON | NOAA-ERL |
| OI - J.M. | WARNOCK | NOAA |
| OI - J.H. | WHITTEKER | DOC-CRC |

BRIEF DESCRIPTION

This experiment was designed to study ionospheric features of a smaller scale than could be detected by the sweep sounder, and to study plasma resonances. Parameters measured were virtual range (a function of propagation time of the reflected pulse) and time. These data were normally observed only when the spacecraft was in range of a telemetry station. The fixed-frequency sounder operated from the same antenna, transmitter, and receiver used for the sweep-frequency experiment. It normally operated for 5 s during the frequency flyback period of the sweep-frequency operation that was every 19 or 29 s. One of six frequencies (0.25, 0.48, 1.00, 1.95, 4.00, or 9.303 MHz) was chosen for use by the experimenter as desired. Other modes of operation were available, including continuous observation at a selected frequency, and a special mixed mode with transmission at the fixed frequency of 0.82 MHz and sweep reception.

BIBLIOGRAPHY

| | | | | | |
|---|---|---|---|---|---|
| 266 | 448 | 449 | 450 | 923 | 944 |

------- ISIS 1, BARRINGTON-----------------------------------------

INVESTIGATION NAME- VLF RECEIVER

NSSDC ID- 69-009A-03 INVESTIGATIVE PROGRAM
CODE EE/CO-OP, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES AND RADIO PHYSICS

PERSONNEL

| | | |
|---|---|---|
| PI - R.E. | BARRINGTON | DOC-CRC |
| OI - F.H. | PALMER | DEFENCE RESEARCH ESTAB |
| OI - H.G. | JAMES | DOC-CRC |

BRIEF DESCRIPTION

The purpose of this experiment was to study natural and man-made VLF signals. Specific objectives included the investigation of VLF propagation phenomena, ion and hybrid plasma resonances, and correlations between VLF emissions and intense fluxes of energetic particles. In this experiment an attempt was made to stimulate the ion resonances of the ambient plasma by using signals from a VLF sweep-frequency exciter, contained within the spacecraft. The instrumentation consisted of a low-frequency, broadband receiver that sensed signals received by the 73-m dipole (split monopole) antenna, between 0.05 and 30 kHz. This same antenna was used for receiving frequencies below 5 MHz on the ionosonde. The receiver had a wide dynamic range (80 dB) that was achieved by use of an automatic gain control system. This VLF experiment included an optional-use onboard exciter that operated over a frequency cycle pattern of 0 to 0.3 to 0 to 11 to 0 kHz over a 3.5-s "frame" period. The frames sequenced through four steps where the transmissions were attenuated by 0, 20, 20, then 40 dB, thus requiring 14 s for one complete cycle of exciter operation. The exciter transmitted on the short antennas and the receiver sensed the signals coupled between the two antennas by the ambient plasma, plus any noise signals which were excited in the plasma. This VLF experiment also permitted antenna impedance measurements, with or without a dc bias on the antenna. The real-time data were transmitted on 136.08-MHz telemetry. The VLF data could be recorded on one of the four tape-recorder channels during the time the tape recorder operated. Tape-recorded and backup real-time data were transmitted on 400-MHz telemetry.

BIBLIOGRAPHY

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 62 | 87 | 447 | 451 | 455 | 569 | 570 | 690 | 714 | 715 |
| 721 | 722 | 723 | 809 | 930 | 931 | 944 | | | |

------- ISIS 1, MCDIARMID----------------------------------------

INVESTIGATION NAME- ENERGETIC PARTICLE DETECTORS

NSSDC ID- 69-009A-04 INVESTIGATIVE PROGRAM
CODE EE/CO-OP, SCIENCE

INVESTIGATION DISCIPLINE(S)
MAGNETOSPHERIC PHYSICS
PARTICLES AND FIELDS

PERSONNEL
PI - I.B. MCDIARMID NATL RES COUNC OF CAN
OI - J.R. BURROWS NATL RES COUNC OF CAN
OI - R.C. ROSE(RETIRED) NATL RES COUNC OF CAN

BRIEF DESCRIPTION
The purpose of this experiment was to provide data that would aid in understanding (1) the mechanisms responsible for the production and control of the outer radiation zone, (2) the related problems of particle entry into the earth's magnetic field, and (3) interactions between the earth's magnetosphere and the solar wind. This experiment consisted of four sets of detectors. The first set, comprising four Geiger counters, measured electrons greater than 20 and 40 keV and protons greater than 300 and 500 keV parallel and perpendicular to the satellite spin axis. All remaining detectors measured particles perpendicular to the spin axis. The second set consisted of solid-state, silicon-junction detectors. These responded to electrons greater than 25 and 140 keV, electrons in the range 230 to 770 keV, and protons greater than 200 and 400 keV. The third set consisted of five silicon-junction detectors that responded to protons between 0.15 and 30 MeV. The fourth set consisted of cesium iodide scintillation photomultiplier systems. Each system operated in two modes and responded to electrons greater than 8, 40, and 60 keV and protons greater than 50 keV and in the range 50 to 70 keV.

BIBLIOGRAPHY

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 151 | 154 | 156 | 423 | 424 | 425 | 532 | 616 | 623 | 624 |
| 821 | 823 | 846 | 944 | 945 | 946 | 956 | | | |

------- ISIS 1, HEIKKILA----------------------------------------

INVESTIGATION NAME- SOFT-PARTICLE SPECTROMETER

NSSDC ID- 69-009A-05 INVESTIGATIVE PROGRAM
CODE EE/CO-OP, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES
PARTICLES AND FIELDS
AERONOMY

PERSONNEL
PI - W.J. HEIKKILA U OF TEXAS, DALLAS
OI - D.M. KLUMPAR U OF TEXAS, DALLAS

BRIEF DESCRIPTION
The purpose of this experiment was to study auroral and ionospheric phenomena by studying low-energy electrons and ions. The spectrometer simultaneously measured the differential energy spectra of positive and negative particles by a divergent electrostatic deflection system with electron multipliers for detectors. The experiment consisted of two such systems--one looking along the satellite spin axis and one perpendicular to it. A programmed power supply provided swept and stepped modes of operation selected either by internal programming or by ground command. The energy range was from 10 eV to 10 keV per unit charge. The swept mode of energy selection provided a 22-point spectrum in 0.5 s, while the stepped mode provided a 20-point (geometrically spaced) spectrum in 40 s. The experiment worked well. NSSDC has all the useful data that exist from this investigation.

BIBLIOGRAPHY

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 101 | 106 | 110 | 112 | 156 | 206 | 262 | 376 | 377 | 386 |
| 387 | 388 | 389 | 390 | 392 | 393 | 394 | 395 | 411 | 445 |
| 453 | 468 | 469 | 470 | 504 | 506 | 532 | 752 | 814 | 827 |
| 942 | 944 | 951 | 952 | 953 | 954 | 955 | 957 | 964 | 966 |

------- ISIS 1, NARCISI----------------------------------------

INVESTIGATION NAME- POSITIVE ION MASS SPECTROMETER (1-20 AMU)

NSSDC ID- 69-009A-06 INVESTIGATIVE PROGRAM
CODE EE/CO-OP, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES
AERONOMY

PERSONNEL
PI - R.S. NARCISI USAF GEOPHYS LAB

BRIEF DESCRIPTION
The ISIS 1 ion mass spectrometer (IMS) experiment was planned to provide in situ measurements of the exospheric ion concentrations, for species having mass-to-charge ratios from 1 to 20, as a function of latitude, longitude, time of day, season, and special events such as solar flares and magnetic storms. Ion concentrations from five ions to 5.E5 ions/cc could be measured. The instrumentation consisted of two mass analyzer assemblies plus a power supply and control unit that generated sweep voltages, bias potentials, and supply voltages. Each analyzer assembly contained a quadrupole mass filter, an electron multiplier, and excitation and detection electronics. The quadrupole rods were 7.62 cm long and 0.38 cm in diameter. The electron multiplier brought ion currents to values greater than 1.E-12 A, and an electrometer amplifier converted output currents to voltages suitable for telemetry. The mass filter was operated at 7 MHz, with the peak radio frequency voltage across the rods at 365 V. The IMS experiment failed during the period of February 2 and 3, 1969.

BIBLIOGRAPHY

944

------- ISIS 1, BRACE----------------------------------------

INVESTIGATION NAME- CYLINDRICAL ELECTROSTATIC PROBES

NSSDC ID- 69-009A-07 INVESTIGATIVE PROGRAM
CODE EE/CO-OP, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES
AERONOMY

PERSONNEL
PI - L.H. BRACE NASA-GSFC
OI - J.A. FINDLAY NASA-GSFC

BRIEF DESCRIPTION
The purpose of this experiment was to study the global variations of electron temperature and electron concentration at S/C altitudes during solar maximum, and to study characteristics of the S/C ion sheath. The measurements were made with two cylindrical probes, operating as Langmuir probes. There were a boom probe and an axial probe. The axial probe extended 48.3 cm from the S/C, along the spin axis, and was centered among the four telemetry antennas on the underside of the S/C. This probe was capable of measurements undisturbed by the satellite motion only when the probe preceded the S/C in its motion through the plasma. The boom probe extended horizontally and outward (in S/C frame of reference) from a boom 1 m long, which in turn extended from an upper surface of the S/C at an angle of about 45 deg to the spin axis. This probe provided some observations during each S/C spin cycle that were free of S/C wake effects. The probes consisted of three concentric, electrically isolated, stainless steel tubes. The outer (0.24-cm diam and 23-cm long) tube floated at its own equilibrium potential and served to place the collector well away from the S/C plasma sheath. The middle tube (0.165-cm diam) extending 23 cm outward from the outer tube acted as an electrical guard for the collector. Its electrical potential was controlled. The collector (0.058-cm diam) extended 23 cm outward from the driven guard. During each 2-min sequence, a volt-ampere curve was obtained from the sawtooth voltage (-2 to +10 V) applied to the collector. This was interpreted in electron densities over a range from 1.E2 to 1.5E6 electrons per cc, and temperatures from about 400 to 5.E4 deg K. NSSDC has all the useful data that exist from this investigation.

BIBLIOGRAPHY

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 106 | 110 | 129 | 130 | 131 | 132 | 208 | 445 | 455 | 518 |
| 534 | 573 | 574 | 643 | 676 | 765 | 781 | 944 | 945 | 950 |

------- ISIS 1, SAGALYN----------------------------------------

INVESTIGATION NAME- SPHERICAL ELECTROSTATIC ANALYZER

NSSDC ID- 69-009A-08 INVESTIGATIVE PROGRAM
CODE EE/CO-OP, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES
AERONOMY

PERSONNEL
PI - R.C. SAGALYN USAF GEOPHYS LAB
OI - M. SMIDDY USAF GEOPHYS LAB

BRIEF DESCRIPTION
The objective of the spherical electrostatic analyzer experiment was to measure the temporal and spatial variations in the concentration and energy distribution of the charged particles throughout the orbit. Specifically, the objectives were to measure the following parameters: (1) the density of positive ions having thermal energy in the concentration range from 1.E1 to 1.E6 ions per cc, (2) the kinetic temperature of the thermal ions in the range from 700 to 4000 deg K, (3) the flux and energy spectrum of protons in the range from 0 to 2 keV, and (4) the satellite potential with respect to the undisturbed plasma. Two units made up the experiment package: a 96-cm boom that supported the sensor and made possible omnidirectional measurements, and an electronics package

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(considered to include the sensor) to perform the measurements and to process the data into a suitable form for telemetry. The sensor was made up of three concentric spherical meshed grids having radii of 3.18, 2.54, and 1.90 cm. The innermost grid was the collector. These grids were made from tungsten mesh and had a transparency of 80 to 90%. To measure the parameters listed above, suitable sweep and step voltages were applied to the grids. This instrument was operated in several modes. The ion densities were sampled 60 times a second, corresponding to a spatial resolution of 150 m. Once per minute the ratio of mass to temperature was sampled, and the energy distribution was sampled once every 2 min. NSSDC has all the useful data that exist from this investigation.

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19 20 21 149 150 231 269 748 795 796
944 948 949

------- ISIS 1, FORSYTH-------------------------------------------

INVESTIGATION NAME- RADIO BEACON

NSSDC ID- 69-009A-09 INVESTIGATIVE PROGRAM
CODE EE/CO-OP, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES AND RADIO PHYSICS

PERSONNEL

| | | | |
|---|---|---|---|
| PI - | P.A. | FORSYTH | WESTERN ONTARIO U |
| OI - | G.F. | LYON | WESTERN ONTARIO U |
| OI - | E.H. | TULL | WESTERN ONTARIO U |

BRIEF DESCRIPTION

This experiment was devised to study the ionospheric irregularities giving special attention to the disturbed ionospheric conditions. Beacon transmitters aboard the satellite radiated polarized radio emissions on command, at 136.41 and 137.95 MHz. The signal polarization, the amplitude of the signal, the relative phase of the signal, and the incident direction of the signal were observed from ground stations. Coincident observations were made at stations about 100 wavelengths apart. From known spacecraft position information and these observations, ionospheric irregularities could be almost completely described in terms of height, horizontal size and shape, electron peak concentration, and radial distribution of electrons. An important part of these descriptions was to originate from the computed values of total electron content (TEC) obtained primarily from the polarization and phase observations.

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234 352 353 354 355 734

------- ISIS 1, HARTZ-------------------------------------------

INVESTIGATION NAME- COSMIC RADIO NOISE

NSSDC ID- 69-009A-10 INVESTIGATIVE PROGRAM
CODE EE/CO-OP, SCIENCE

INVESTIGATION DISCIPLINE(S)
ASTRONOMY
IONOSPHERES AND RADIO PHYSICS

PERSONNEL

| | | | |
|---|---|---|---|
| PI - | T.R. | HARTZ(RETIRED) | DOC-CRC |

BRIEF DESCRIPTION

This experiment used the sweep-frequency ionosonde receiver automatic gain control voltage to measure galactic and solar radio noise levels. The receiver swept from 0.1 to 20 MHz. The dynamic range was 50 dB, and the bandwidth was 55 kHz. The antennas used were 18.7-m and 73-m dipoles.

BIBLIOGRAPHY

23 376 377 445 446 451 454 944

*************************** ISIS 2***************************

SPACECRAFT COMMON NAME- ISIS 2
ALTERNATE NAMES- ISIS-B, PL-701F
05104

NSSDC ID- 71-024A

LAUNCH DATE- 04/01/71 WEIGHT- 256. KG
LAUNCH SITE- VANDENBERG AFB, UNITED STATES
LAUNCH VEHICLE- DELTA

SPONSORING COUNTRY/AGENCY

| | |
|---|---|
| CANADA | DOC-CRC |
| UNITED STATES | NASA-OSSA |
| JAPAN | RRL |

INITIAL ORBIT PARAMETERS

| | |
|---|---|
| ORBIT TYPE- GEOCENTRIC | EPOCH DATE- 04/02/71 |
| ORBIT PERIOD- 113.5 MIN | INCLINATION- 88.1 DEG |
| PERIAPSIS- 1358. KM ALT | APOAPSIS- 1428. KM ALT |

PERSONNEL

| | | | |
|---|---|---|---|
| PM - | C.A. | FRANKLIN | DOC-CRC |
| PM - | L.H. | BRACE | NASA-GSFC |
| PS - | L.H. | BRACE | NASA-GSFC |
| PS - | T.R. | HARTZ(RETIRED) | DOC-CRC |
| PS - | J.E. | JACKSON | NASA-GSFC |

BRIEF DESCRIPTION

ISIS 2 was an ionospheric observatory instrumented with a sweep- and a fixed-frequency ionosonde, a VLF receiver, energetic and soft particle detectors, an ion mass spectrometer, an electrostatic probe, a retarding potential analyzer, a beacon transmitter, a cosmic noise experiment, and two photometers. Two long crossed-dipole antennas (73 and 18.7 m) were used for the sounding, VLF, and cosmic noise experiments. The spacecraft was spin-stabilized to about 2 rpm after antenna deployment. There were two basic orientation modes for the spacecraft, cartwheel and orbit-aligned. The spacecraft operated approximately the same length of time in each mode, remaining in one mode typically 3 to 5 months. The cartwheel mode with the axis perpendicular to the orbit plane was made available to provide ram and wake data for some experiments for each spin period, rather than for each orbit period. Attitude and spin information was obtained from a three-axis magnetometer and a sun sensor. Control of attitude and spin was possible by means of magnetic torquing. The experiment package also included a programmable tape recorder with a 1-h capacity. For nonrecorded observations, data from satellite and subsatellite regions were telemetered when the spacecraft was in the line of sight of a telemetry station. Telemetry stations were located so that primary data coverage was near the 80-deg-W meridian and near Hawaii, Singapore, Australia, England, France, Norway, India, Japan, Antarctica, New Zealand, and Central Africa. NASA support of the ISIS project was terminated on October 1, 1979. A significant amount of experimental data, however, was acquired after this date by the Canadian project team. ISIS 2 operations were terminated in Canada on March 9, 1984. The Radio Research Laboratories (Tokyo, Japan) then requested and received permission to reactivate ISIS 2. Regular ISIS 2 operations were started from Kashima, Japan, in early August 1984.

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27 158 224 309 311 381 446 508 526 537
632 679 756 828 832 906 909

------- ISIS 2, WHITTEKER-------------------------------------------

INVESTIGATION NAME- SWEEP-FREQUENCY SOUNDER

NSSDC ID- 71-024A-01 INVESTIGATIVE PROGRAM
CODE EE/CO-OP, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES AND RADIO PHYSICS

PERSONNEL

| | | | |
|---|---|---|---|
| PI - | J.H. | WHITTEKER | DOC-CRC |
| OI - | J. | TURNER | IONOSPHERIC PRED SERV |
| OI - | M. | SYLVAIN | LGE |
| OI - | O. | HOLT | AURORAL OBS |
| OI - | Y. | OGATA | RADIO RESEARCH LAB |
| OI - | R. | RAGHAVARAO | PHYSICAL RESEARCH LAB |
| OI - | J.E. | JACKSON | NASA-GSFC |
| OI - | R.B. | NORTON | NOAA-ERL |
| OI - | K.L. | CHAN | NASA-ARC |
| OI - | R.S. | UNWIN | DEPT OF SCI+INDUST RES |

BRIEF DESCRIPTION

The purpose of this experiment was to measure the ionospheric electron density in the altitude range 300 to 1400 km. Another important function of the sounder was to provide correlative data for the other ISIS 2 experiments, particularly those measuring ionospheric parameters. The ISIS 2 ionosonde was a radio transmitter that recorded the time delay between a transmitted and returned radio-frequency pulse. A continuum of frequencies between 0.1 and 20 MHz was sampled every 14 or 21 s, and one of six selected frequencies was also used for sounding for a few seconds during each 14- or 21-s period. In addition to the sweep- and fixed-frequency modes of operation, a mixed mode was available in which the transmitter frequency was fixed at one of six possible frequencies while the receiver swept. Several virtual-range (delay-time) traces resulting from ground reflections, plasma resonances, birefringence of the ionosphere, nonvertical propagation, etc., were normally observed. Virtual range at a given frequency was primarily a function of distance traversed by the signal, electron density along the propagation path, and mode of propagation. The standard data format was an ionogram (graph) showing virtual range as a function of radio frequency.

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314 338 343 356 416 426 431 444 447 448
449 450 452 453 480 505 508 516 517 542
581 594 601 637 639 652 669 673 674 675
678 679 720 733 751 752 753 762 763 777
784 785 788 789 790 816 827 828 832 835
836 861 881 890 918 942 943 945 946

------- ISIS 2, CALVERT-------------------------------------------

INVESTIGATION NAME- FIXED-FREQUENCY SOUNDER

NSSDC ID- 71-024A-02

INVESTIGATIVE PROGRAM
CODE EE/CO-OP, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES AND RADIO PHYSICS

PERSONNEL

| | | |
|---|---|---|
| PI - W. | CALVERT | U OF IOWA |
| OI - R.B. | NORTON | NOAA-ERL |
| OI - J.H. | WHITTEKER | DOC-CRC |
| OI - J.M. | WARNOCK | NOAA |

BRIEF DESCRIPTION

This experiment was designed to study ionospheric features of a smaller scale than could be detected by the sweep sounder and to study plasma resonances. Parameters measured were virtual range (a function of propagation time of the pulse) and time. These data were normally observed only when the spacecraft was in range of a telemetry station. The fixed-frequency sounder operated from the same antenna, transmitter, and receiver used for the sweep-frequency experiment. It normally operated for 3 to 5 s during the frequency flyback period of the sweep-frequency operation which was every 14 or 21 s. One of six frequencies (0.12, 0.48, 1.00, 1.95, 4.00, or 9.303 MHz) was chosen for use by the experimenter, as desired. Other modes of operation were available, including continuous observation at a selected frequency and a special mixed mode with transmission at a selected one of the six fixed frequencies and sweep reception.

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| 100 | 432 | 448 | 449 | 450 | 831 |

------- ISIS 2, BARRINGTON-------------------------------------------

INVESTIGATION NAME- VLF RECEIVER

NSSDC ID- 71-024A-03

INVESTIGATIVE PROGRAM
CODE EE/CO-OP, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES AND RADIO PHYSICS

PERSONNEL

| | | |
|---|---|---|
| PI - R.E. | BARRINGTON | DOC-CRC |
| OI - F.H. | PALMER | DEFENCE RESEARCH ESTAB |
| OI - H.G. | JAMES | DOC-CRC |

BRIEF DESCRIPTION

The purpose of this experiment was to study natural and man-made VLF signals. Specific objectives included the investigation of VLF propagation phenomena, ion and hybrid plasma resonances, and correlations between VLF emissions and intense fluxes of energetic particles. In this experiment a sweep-frequency exciter, covering the range from 15 kHz down to 0.05 kHz in 1.0 s, was used to stimulate ion resonances in the plasma. The instrumentation consisted of a low-frequency broadband receiver that observed signals from the 73-m long dipole (split monopole) antenna between 0.05 and 30 kHz. This same antenna was used for receiving signals below 5 MHz on the ionosonde. The VLF receiver had a wide dynamic range that was achieved by use of an automatic gain control system. The experiment also permitted antenna impedance measurements, with or without a dc bias on the antenna. The real-time data were transmitted on 136.08-MHz telemetry. The VLF data could be recorded on one of the four tape-recorder channels when the spacecraft tape-recorder was operating. Tape-recorded and backup real-time data were transmitted on 400-MHz telemetry.

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|---|---|---|---|---|---|---|---|---|---|
| 86 | 87 | 88 | 158 | 268 | 273 | 363 | 364 | 417 | 419 |
| 420 | 422 | 447 | 508 | 522 | 523 | 570 | 679 | 690 | 715 |
| 718 | 719 | 720 | 721 | 722 | 723 | 733 | 828 | 836 | 881 |
| 882 | 921 | 930 | 931 | | | | | | |

------- ISIS 2, MCDIARMID-------------------------------------------

INVESTIGATION NAME- ENERGETIC PARTICLE DETECTORS

NSSDC ID- 71-024A-04

INVESTIGATIVE PROGRAM
CODE EE/CO-OP, SCIENCE

INVESTIGATION DISCIPLINE(S)
MAGNETOSPHERIC PHYSICS
PARTICLES AND FIELDS

PERSONNEL

| | | |
|---|---|---|
| PI - I.B. | MCDIARMID | NATL RES COUNC OF CAN |
| OI - J.R. | BURROWS | NATL RES COUNC OF CAN |

BRIEF DESCRIPTION

The objectives of the energetic particle experiment were to provide data that would aid in the understanding of (1) the mechanisms responsible for the production and control of the outer radiation zone, (2) the related problem of solar-flare particle entry into the earth's magnetic field, and (3) interactions between the earth's magnetosphere and the solar wind. This experiment consisted of four sets of detectors. The first set consisted of three Geiger counters (one of which failed after launch) and measured electrons greater than 20 and 40 keV perpendicular and parallel to the spin axis. These Geiger counters were also sensitive to protons with energies greater than 240 and 600 keV, respectively. All remaining detectors measured particles perpendicular to the spin axis. The second set consisted of two solid-state, silicon-junction detectors. Both detectors were operated in low- and high-threshold mode, while one could additionally be switched to another discrimination level. They measured electrons with energies greater than 40, 60, 90, 120, 150, and 200 keV. They were also sensitive to protons with energies greater than 150, 200, and 750 keV. The switchable detector experienced continuous saturation. The third set consisted of three silicon-junction detectors that measured protons in the energy ranges 0.8 to 4.0, 3.2 to 12.7, and 12.9 to 28.0 MeV, alpha particles in the energy range 2.5 to 16.0 MeV, and electrons in the energy range 1.0 to 2.0 MeV. The fourth set was composed of two cesium iodide scintillation-photomultiplier systems (channeltrons with cylindrical electrostatic analyzers) stepped through eight energies in 64/60 of a second. These differential spectrometers measured electrons at 9.6, 7.8, 6.0, 4.1, 3.0, 2.2, 1.3, and 0.15 keV, and measured protons at 26.2, 21.6, 17.0, 12.4, 9.4, 7.6, 5.2, and 2.2 keV.

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|---|---|---|---|---|---|---|---|---|---|
| 146 | 152 | 157 | 158 | 230 | 312 | 314 | 423 | 447 | 508 |
| 516 | 557 | 561 | 582 | 604 | 624 | 625 | 626 | 627 | 628 |
| 629 | 631 | 632 | 652 | 679 | 783 | 785 | 786 | 827 | 828 |
| 836 | 895 | 901 | 919 | 921 | 937 | 945 | 946 | 960 | |

------- ISIS 2, HEIKKILA-------------------------------------------

INVESTIGATION NAME- SOFT-PARTICLE SPECTROMETER

NSSDC ID- 71-024A-05

INVESTIGATIVE PROGRAM
CODE EE/CO-OP, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES
PARTICLES AND FIELDS
AERONOMY

PERSONNEL

| | | |
|---|---|---|
| PI - W.J. | HEIKKILA | U OF TEXAS, DALLAS |
| OI - D.M. | KLUMPAR | U OF TEXAS, DALLAS |

BRIEF DESCRIPTION

The soft-particle spectrometer (basically an electrostatic analyzer) was used to study the directional intensity and differential energy spectra of ions and electrons to obtain a greater understanding of auroras, geomagnetic disturbances, and various ionospheric features. Differential energy spectra were obtained in the energy range 5 eV to 15 keV with a 20% energy resolution. The voltage sweep program of the analyzer was flexible. The experiment worked well from launch until October 1969, when the ion part of the experiment failed. Subsequently, only electron data were acquired. NSSDC has all the useful data that exist from this investigation.

BIBLIOGRAPHY

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 24 | 146 | 147 | 157 | 158 | 182 | 230 | 248 | 251 | 262 |
| 312 | 313 | 315 | 391 | 434 | 446 | 447 | 453 | 464 | 468 |
| 470 | 501 | 502 | 504 | 505 | 506 | 507 | 508 | 509 | 510 |
| 516 | 561 | 582 | 604 | 626 | 631 | 679 | 689 | 752 | 754 |
| 784 | 785 | 786 | 787 | 826 | 827 | 828 | 831 | 835 | 836 |
| 837 | 859 | 894 | 895 | 921 | 939 | 942 | 945 | 946 | 955 |
| 957 | 958 | 959 | 964 | | | | | | |

------- ISIS 2, HOFFMAN-------------------------------------------

INVESTIGATION NAME- ION-MASS SPECTROMETER

NSSDC ID- 71-024A-06

INVESTIGATIVE PROGRAM
CODE EE/CO-OP, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES
AERONOMY

PERSONNEL

| | | |
|---|---|---|
| PI - J.H. | HOFFMAN | U OF TEXAS, DALLAS |

BRIEF DESCRIPTION

The magnetic ion-mass spectrometer experiment was flown to measure the distribution of the concentrations of the positive ion species as a function of time and position, with particular interest focused on the polar wind particles. The instrument had two ion detector systems, and mass scanning through the range from 1 to 64 atomic mass units (u) was accomplished in two sections, 1 to 8 u and 8 to 64 u. Two ion beams emerged from the magnetic sector of the instrument and were simultaneously detected by electron multipliers and log electrometer amplifiers. A circuit following each amplifier detected the peak amplitude of the ion current. This peak value, rather than the entire mass spectrum, was transmitted in order to reduce the required telemetry bandwidth. In this mode of operation, the complete mass range was scanned in 1 s. A backup mode was provided that produced an analog output with a sweep period of 8 s. This experiment operated nominally after launch with most of the data obtained in the peak mode and while the satellite operated in the cartwheel mode. For about

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2 min per pass over Ottawa, Canada, the experiment operated in the analog mode. Inflight calibration was achieved by comparing ion concentration measurements at appropriate altitudes, i.e., where a single ion species predominated, with electron density data from the sounder on board. Other comparisons were made between the spectrometer output and measurements obtained from other related experiments on board. NSSDC has all the useful data that exist from this investigation.

BIBLIOGRAPHY

133 136 158 208 224 314 315 406 407 408
410 447 508 519 575 581 679 828 831 835
836 881 882 945

------- ISIS 2, BRACE------------------------------------------

INVESTIGATION NAME- CYLINDRICAL ELECTROSTATIC PROBES

NSSDC ID- 71-024A-07

INVESTIGATIVE PROGRAM
CODE EE/CO-OP, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES
AERONOMY

PERSONNEL
PI - L.H. BRACE NASA-GSFC
OI - J.A. FINDLAY NASA-GSFC

BRIEF DESCRIPTION

The purpose of this experiment was to study the global variations of electron temperature and electron concentration at spacecraft altitudes during the waning phase of the solar cycle. The measurements were made with two cylindrical probes mounted along the spin axis, one at each end of the spacecraft. The sensors were operated as Langmuir probes, with the probe current being measured as a function of probe voltage. Although basically the same cylindrical probe experiment was flown on ISIS 1, the ISIS 2 probe provided (1) greater sensitivity allowing a more complete coverage of low-density regions such as the region over the polar cap, (2) very high resolution of plasma structure (down to 10 m in extent), and (3) onboard signal processing with backup to provide data in the format that had been used for the ISIS 1 experiment. NSSDC has all the useful data that exist from this investigation.

BIBLIOGRAPHY

39 130 133 146 158 208 224 251 314 447
475 508 519 575 581 644 652 679 828 831
832 835 836 945

------- ISIS 2, MAIER------------------------------------------

INVESTIGATION NAME- RETARDING POTENTIAL ANALYZER

NSSDC ID- 71-024A-08

INVESTIGATIVE PROGRAM
CODE EE/CO-OP, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES
AERONOMY

PERSONNEL
PI - E.J. MAIER NASA-GSFC
OI - B.E. TROY, JR. US NAVAL RESEARCH LAB
OI - J.L. DONLEY NASA-GSFC

BRIEF DESCRIPTION

The primary objective of this experiment was to measure the positive ion density, composition, and temperature in the vicinity of the spacecraft. A secondary objective was to measure the thermal electron density and temperature, and the flux of suprathermal electrons. This retarding potential analyzer consisted of three grids (aperture grid, retarding grid, and suppressor grid) that provided a volt-ampere curve relating sweep voltage on the retarding grid to current flow to the collector. Analysis of the volt-ampere curves provided ion/electron temperatures and densities. This experiment was designed to operate only with the satellite in a cartwheel mode of operation. In this mode, the spin axis was perpendicular to the orbit plane. This allowed the analyzer aperture to face the direction of satellite motion once each spin period. NSSDC has all the useful data that exist from this investigation.

BIBLIOGRAPHY

158 314 475 508 575 580 581 582 679 828
831 835 891 945

------- ISIS 2, FORSYTH------------------------------------------

INVESTIGATION NAME- RADIO BEACON

NSSDC ID- 71-024A-09

INVESTIGATIVE PROGRAM
CODE EE/CO-OP, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES AND RADIO PHYSICS

PERSONNEL
PI - P.A. FORSYTH WESTERN ONTARIO U
OI - G.F. LYON WESTERN ONTARIO U
OI - E.H. TULL WESTERN ONTARIO U

BRIEF DESCRIPTION

A continuous-wave transmitter (137 to 138 MHz band) radiating about 100 mW and operating in conjunction with the tracking beacon (136 to 137 MHz band) provided facilities for observing scintillations from irregularities, determining magnitudes and positions, and evaluating electron content between ground observer and satellite.

BIBLIOGRAPHY

353 354 355

------- ISIS 2, HARTZ------------------------------------------

INVESTIGATION NAME- COSMIC RADIO NOISE

NSSDC ID- 71-024A-10

INVESTIGATIVE PROGRAM
CODE EE/CO-OP, SCIENCE

INVESTIGATION DISCIPLINE(S)
ASTRONOMY
IONOSPHERES AND RADIO PHYSICS

PERSONNEL
PI - T.R. HARTZ(RETIRED) DOC-CRC

BRIEF DESCRIPTION

This experiment used the sweep-frequency ionosonde receiver automatic gain control voltages to measure galactic and solar radio-noise levels. The receiver swept from 0.1 to 20 MHz. The dynamic range was 50 dB, and the bandwidth was 55 kHz. The antennas used were 18.7-m and 73-m dipoles.

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23 446 454 501 784 790

------- ISIS 2, ANGER------------------------------------------

INVESTIGATION NAME- 3914- AND 5577-A PHOTOMETER

NSSDC ID- 71-024A-11

INVESTIGATIVE PROGRAM
CODE EE/CO-OP, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES
PARTICLES AND FIELDS
AERONOMY

PERSONNEL
PI - C.D. ANGER U OF CALGARY

BRIEF DESCRIPTION

This dual-wavelength scanning auroral photometer was designed to map the distribution of auroral emissions at 5577 and 3914 A over the portion of the dark earth visible to the spacecraft. A combination of internal electronic scanning performed by an image dissector and of the natural orbital and rotational motions of the spacecraft permitted the sensor to systematically scan across the earth. The detector system was constructed to allow incident radiation to be accepted from two directions 180 deg apart, and then to focus this light at a common point on the single-image-dissector photometer tube. Only one of the two optical systems pointed at the earth at any one time, while the other faced into space. When the spacecraft spin axis was oriented to lie in the orbital plane, each rotation of the spacecraft resulted in an earth scan 5 deg wide. This width size was chosen to ensure overlap with the previous scan. The image dissector repetitively scanned at a high speed across the narrow dimension of each 5-deg band and divided it into separately resolved regions 0.4 deg by 0.4 deg. Similar strips were scanned at each of the two wavelengths, but at times which differed by half the rotation period of about 10 s. A calibration light source for each wavelength was built into the optical assembly, and a calibration cycle was initiated automatically whenever a "power on" command was given. To minimize the problems arising from solar illumination of the optics and the direct viewing of the sunlit earth, a sunlight protection system was included. Complete details about the experiment can be found in C. D. Anger et al., "The ISIS-II scanning auroral photometer," Applied Optics, v. 12, n. 8, pp. 1753-1766, August 1973.

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687 826 827 828 831 833 834 835 837 895
915 920 921 946 947 958

------- ISIS 2, SHEPHERD------------------------------------------

INVESTIGATION NAME- 6300-A PHOTOMETER

NSSDC ID- 71-024A-12

INVESTIGATIVE PROGRAM
CODE EE/CO-OP, SCIENCE

INVESTIGATION DISCIPLINE(S)
IONOSPHERES
PARTICLES AND FIELDS
AERONOMY

PERSONNEL
PI - G.G. SHEPHERD YORK U

BRIEF DESCRIPTION

A two-channel photometer was used to measure directly and to map the intensity of the atomic oxygen red line at 6300 A in day, twilight, and night airglow and aurora. Each channel had its own optical input, and the two inputs were mounted at the same end of the spacecraft, separated by 180 deg, with their axes at 90 deg to the spacecraft's spin axis. One optical input was characterized by a spectral bandwidth of 12 A centered around the 6300-A line of atomic oxygen, and the other input was used for white-light measurements. The spinning satellite caused the photometer to alternately view the earth and then the sky; i.e., when one sensor viewed the earth, the other sensor saw the dark sky. Both sensors had a 2.5-deg circular field of view. With the use of a beam-combiner arrangement, the same photomultiplier accepted the two inputs. The dynamic range of intensity measurements was from about 1.E11 photons/(sq m-s) (10 rayleighs) to more than 1.E16 photons/(sq m-s). Sunlight could enter the optical systems directly in addition to earth-reflected light. The instrument baffle was illuminated by the sun only for the off-axis angles less than 47 deg. Outside this limit, the data were not degraded by sunlight, permitting normal operation in the region of the orbit where the spacecraft was in sunlight, but the portion of the earth beneath it was dark. An external light source "saw" the filter only when it was 7.5 deg or less off axis. In the range 7.5 to 47 deg, good data were still obtained when the sunlit earth was the origin of the contamination. To perform the data analysis, it was necessary, among other operations, to evaluate different geometrical situations, and to locate the point at which the 12-A bandpass photometer's FOV crosses the earth's leading limb so that the data could be organized into spin maps. For more details see G. G. Shepherd et al. "ISIS-II atomic oxygen red line photometer," Applied Optics, v. 12, n. 8, pp. 1757-1774, August 1973.

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| 651 | 679 | 683 | 740 | 741 | 824 | 825 | 826 | 827 | 828 |
| 829 | 830 | 831 | 832 | 833 | 834 | 835 | 836 | 837 | 838 |
| 839 | 840 | 946 | 955 | 958 | | | | | |

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# Appendix A - Definitions

# APPENDIX A - DEFINITIONS

NLA - No Longer Affiliated. Used in the spacecraft personnel section to indicate that the person had the specified affiliation at the time of his participation in the project, but is no longer there. Used in the investigation personnel section to indicate that the affiliation shown is the last known scientific affiliation and that the given person is no longer there.

NSSDC ID - An identification code used in the NSSDC information system. In this system, each successfully launched spacecraft and experiment is assigned a code based on the launch sequence of the spacecraft. This code (e.g., 69-009A for the spacecraft ISIS 1) corresponds to the COSPAR international designation. The experiment codes are based on the spacecraft code. For example, the experiments carried aboard the spacecraft 69-009A are numbered 69-009A-01, 69-009A-02, etc. Similarly, data sets corresponding to experiment 69-009A-01 are coded 69-009A-01A, -01B, etc. Each prelaunch spacecraft and experiment is also assigned an NSSDC ID code based on the name of the spacecraft. For example, the approved NASA mission Solar Mesosphere Explorer was coded SME prior to launch. The experiments carried aboard this spacecraft were coded SME -01, SME -02, etc. Once it was launched, its prelaunch designation was changed to a postlaunch one: 81-100A.

OI - Other Investigator.

PI - Principal Investigator.

PM - Project Manager. If a spacecraft has had several project managers, the initial and the latest project managers are both indicated in the spacecraft personnel section. For international programs there is usually a project manager in each of the two principal participating nations. The current or more recent PM is listed first.

PS - Project Scientist. The above comment for project managers also applies to project scientists.

# Appendix B - List of Documents Available From NSSDC and Request Forms

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## LIST OF DOCUMENTS AVAILABLE FROM NSSDC*
(April 1986)

| NSSDC Order Number | Publication Title |
|---|---|
| **DOCUMENTS DESCRIBING THE OPERATION OF NSSDC AND WDC-A-R&S** | |
| NSSDC/WDC-A-R&S 84-19 | Guidelines for Submitting Data to the National Space Science Data Center |
| NSSDC/WDC-A-R&S 86-02 | NSSDC and WDC-A-R&S Document Availability and Distribution Services |
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| NSSDC/WDC-A-R&S 85-01 | Report on Active and Planned Spacecraft and Experiments (February 1985) |
| NSSDC/WDC-A-R&S 85-05 | NSSDC Data Listing (July 1985) |
| | NSSDC Newsletter (a quarterly publication) |
| **DOCUMENTS DESCRIBING DATA MANAGEMENT SYSTEMS** | |
| | The Pilot Climate Data System Brochure |
| | The Pilot Climate Data System Catalog |
| | Advancements in Land Resource Data Management: Pilot Land Data System |
| | Advancements in Land Science Management: Pilot Land Data System |
| | The Development of a Prototype Intelligent Interface for NASA's Scientific Database Systems |
| GSFC X-931-82-14 | Crustal Dynamics Data Information System User's Guide |

*This list contains documents which are available as hardcopy and which will be provided as hardcopy until the supply is depleted; then they will be provided on microfiche. Earlier editions of documents, such as *NSSDC Data Listing* and *Report on Active and Planned Spacecraft and Experiments*, which are not listed, are available on microfiche. The dagger symbol (†) following a listed document title signifies that the document is now provided on microfiche.

## DOCUMENTS DESCRIBING THE AVAILABILITY OF EXPERIMENT DATA

### Astronomy

| | |
|---|---|
| NSSDC 74-15c | Data Catalog of Satellite Experiments - Astronomy and Solar Physics† |
| NSSDC/WDC-A-R&S 78-05 | Directory of Astronomical Data Files |
| NASA TM RP 1118 | Catalog of Infrared Observations† |
| NSSDC/WDC-A-R&S 80-07 | Astronomical Data Center Bulletin, Vol. 1, No. 1 |
| NSSDC/WDC-A-R&S 81-09 | Astronomical Data Center Bulletin, Vol. 1, No. 2 |
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| NSSDC/WDC-A-R&S 82-01 | Digest of Celestial X-Ray Missions and Experiments |
| NSSDC/WDC-A-R&S 84-13 | Data Announcement Bulletin: Availability of Infrared Astronomical Satellite (IRAS) Data Sets from NSSDC |

### Ionospheric Physics

| | |
|---|---|
| NSSDC 74-15a | Data Catalog of Satellite Experiments: Ionospheric Physics, Meteorology, and Planetary Atmospheres |
| NSSDC 75-07 | Catalog of Ionospheric and Atmospheric Data |
| NSSDC/WDC-A-R&S 80-03 | Coordinated Ionospheric and Magnetospheric Observations from the ISIS 2 Satellite by the ISIS 2 Experimenters, Vol. 1, Optical Auroral Images and Related Direct Measurements |
| NSSDC/WDC-A-R&S 80-05 | Coordinated Ionospheric and Magnetospheric Observations from the ISIS 2 Satellite by the ISIS 2 Experimenters, Vol. 3, High-Latitude Charged Particle, Magnetic Field and Ionospheric Plasma Observations During Northern Summer |
| NSSDC/WDC-A-R&S 80-09 | Coordinated Ionospheric and Magnetospheric Observations from the ISIS 2 Satellite by the ISIS 2 Experimenters, Vol. 2, Auroral Optical Emissions, Magnetic Field Perturbations, and Plasma Characteristics, Measured Simultaneously on the Same Magnetic Field Line |
| NSSDC/WDC-A-R&S 81-01 | Coordinated Ionospheric and Magnetospheric Observations from the ISIS 2 Satellite by the ISIS 2 Experimenters, Vol. 4, A. Large Storms B. Airglow and Related Measurements C. VLF Observations |

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## DOCUMENTS DESCRIBING THE AVAILABILITY OF EXPERIMENT DATA (Continued)

### Meteorology and Remote Sensing

| | |
|---|---|
| | The Nimbus 5 User's Guide |
| | The Nimbus 5 Data Catalog, Vols. 1-12† |
| | The Nimbus 6 User's Guide |
| | The Nimbus 6 Data Catalog, Vols. 1-12† |
| | The Nimbus 7 User's Guide |
| | Nimbus 7 Flight Evaluation Reports 1-4† |
| | The GOES/SMS User's Guide† |
| | Heat Capacity Mapping Mission (HCMM) User's Guide |
| | HCMM Information Packet (Data Catalog, Users Guide, Day/Night Image Catalog, Documentation) |
| | Magsat Information Packet |
| NSSDC 74-15a | Data Catalog of Satellite Experiments - Ionospheric Physics, Meteorology, and Planetary Atmospheres |
| NSSDC/WDC-A-R&S 82-25 | Data Announcement Bulletin: Space Shuttle OSTA 1 Payload Data |
| | OSTA 1 Experiments |
| NSSDC/WDC-A-R&S 84-09 | Data Announcement Bulletin: The SIR-A Movie |

### Particles and Fields

| | |
|---|---|
| NSSDC 75-02 | Catalog of Particles and Fields Data 1958-1965 |
| NSSDC 75-03 | Catalog of Particles and Fields Data 1966-1973 |
| NSSDC/WDC-A-R&S 77-04 | Interplanetary Medium Data Book |
| NSSDC/WDC-A-R&S 77-04a | Interplanetary Medium Data Book - Appendix |
| NSSDC/WDC-A-R&S 79-08 | Interplanetary Medium Data Book, Supplement 1 |
| NSSDC/WDC-A-R&S 83-01 | Interplanetary Medium Data Book, Supplement 2 |
| NSSDC/WDC-A-R&S 86-04 | Interplanetary Medium Data Book, Supplement 3 |
| NSSDC/WDC-A-R&S 82-28 | Data Announcement Bulletin: Availability of IMP-J (IMP 8) Interplanetary Field and Plasma Data for the International Magnetospheric Study Period (IMS) |

### Planetary Atmospheres

| | |
|---|---|
| NSSDC 74-15a | Data Catalog of Satellite Experiments - Ionospheric Physics, Meteorology, and Planetary Atmospheres |
| NSSDC 75-07 | Catalog of Ionospheric and Atmospheric Data |

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## DOCUMENTS DESCRIBING THE AVAILABILITY OF EXPERIMENT DATA (Continued)

### Planetology

| | |
|---|---|
| NSSDC 74-15d | Data Catalog of Satellite Experiments - Planetology† |
| NSSDC 69-05 | Lunar Orbiter Photographic Data Package† |
| NSSDC 76-02 | Status of Availability of Lunar Orbiter TV Pictures |
| NSSDC 70-06 | Apollo 11 Lunar Photographic Data Package† |
| NSSDC 70-09 | Apollo 12 Lunar Photographic Data Package† |
| NSSDC 70-18 | Apollo 13 Lunar Photographic Data Package† |
| NSSDC 71-16 | Apollo 14 Lunar Photographic Data Package† |
| NSSDC 72-07 | Apollo 15 Lunar Photographic Data Package† |
| NSSDC 73-01 | Apollo 16 Lunar Photographic Data Package† |
| NSSDC 74-08 | Apollo 17 Lunar Photographic Data Package† |
| NSSDC/WDC-A-R&S 77-02 | Catalog of Lunar Mission Data |
| NSSDC/WDC-A-R&S 78-03 | Lunar Transient Phenomena Catalog† |
| NSSDC 71-09 | Mariner 6 and 7 Photographic Data† |
| NSSDC 73-03 | Mariner 9 Data Announcement Bulletin† |
| NSSDC 74-05 | Mariner 9 Data Announcement Bulletin Supplement† |
| JPL TM 33-595-VL1 | Mariner Mars 71 TV Picture Catalog, Vol. 1 |
| JPL TM 33-585-VL2 | Mariner Mars 71 TV Picture Catalog, Vol. 2 |
| JPL TM 33-595 | Mariner 9 TV Picture Microfiche Library Users Guide |
| JPL TM 33-628 | Users Guide to Mariner 9 TV RDR |
| JPL TM 33-723 | Guide to User of Mariner Images |
| NSSDC 75-18 | Status of Availability of Mariner 10 TV Pictures† |
| NSSDC 76-01 | Zond 8 Lunar Photography Data Announcement Bulletin† |
| NSSDC/WDC-A-R&S 78-01 | Catalog of Viking Mission Data |
| NASA RP-1007 | Viking Lander Imaging Investigations |
| NSSDC/WDC-A-R&S 80-11 | Apollo Seismological Investigations Data User's Note |

### Solar Physics

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| NSSDC 74-15c | Data Catalog of Satellite Experiments - Astronomy and Solar Physics† |

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## REPORTS ON MODELS OF THE NEAR-EARTH ENVIRONMENT

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| GSFC X-601-72-487 | A Model of the Starfish Flux in the Inner Radiation Zone† |
| JSR, 12, 2 Feb. '75 | Energetic Solar Proton vs. Terrestrially Trapped Proton Fluxes for the Active Years 1977-1983† |
| JSR, 11, 6 June '74 | Solar Proton Fluences for 1977-1983† |
| NASA SP-3024 | Models of the Trapped Radiation Environment, Vol. VII: Long-Term Time Variations |
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| NSSDC 72-11 | The Use of Inner Zone Electron Model AE † |
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| NSSDC 72-13 | A Model Environment for Outer Zone Electrons† |
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| NSSDC 74-03 | A Model of the Trapped Electron Population for Solar Minimum |
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| NASA SP-3054 | World Maps of Constant B, L, and Flux Constants† |
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| GSFC X-645-72-301 | Average Daily Variations in the Magnetic Field as Observed by ATS 5† |

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LIST OF DOCUMENTS AVAILABLE FROM NSSDC (CONTINUED)

## ROCKET AND SATELLITE INFORMATION AND DATA EXCHANGE DOCUMENTS

| | |
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| NSSDC/WDC-A-R&S 78-02 | Launch Summary for 1973-77† |
| NSSDC/WDC-A-R&S 84-01 | Launch Summary for 1978-1982 |
| GSFC X-601-72-002 | The National Space Science Data Center Guide to International Rocket Data† |

## IMS/SSC REPORTS AND OTHER ORBIT INFORMATION

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| IMS/SSC Report No. 9 | IMS Directory of Spacecraft and Experiments Scientific Contacts - Final Update October 1980 |
| GSFC X-692-70-64 | Trajectories of Explorers 33, 34, and 35 July 1966-April 1969 |
| GSFC X-692-73-291 | Trajectories of Explorers 33, 35, 41, 43, and 47 May 1969 - December 1972 |
| GSFC X-601-76-38 | Trajectories of Explorers 43, 47, and 50 September 1972 - December 1975† |
| NSSDC/WDC-A-R&S 86-03 | Trajectories of Pioneers 6-11, Helios A and B and Voyagers 1 and 2 |
| Circular Letter Nr 7 | CCOG Handbook for the IMS-GEOS (Period 1976-79)† |
| Circular Letter Nr 8 | Supplement to the CCOG Handbook for the IMS-GEOS (Period 1976-79) |

## DATA ANALYSIS WORKSHOP CENTER (DAWOC)

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| NSSDC/WDC-A-R&S 79-02 | An Evolutionary Approach to the Group Analysis of Global Geophysical Data |
| CDAW 1.0 Data Catalog | The IMS Events of December 1 1500h-December 2 2400h, 1977 and December 11 2100h-December 12 0730h, 1977 |
| CDAW 2.1 Data Catalog | The IMS Events of July 28 1200h-July 29 2000h, 1977 |
| CDAW 3.0 Data Catalog | ISEE 1 and ISEE 2 Bow Shock Crossings |
| CDAW 4.0 Data Catalog | ISEE 1 and ISEE 2 Magnetopause Crossings |
| CDAW 6.3 Data Catalog | An IMS Study: Energy Transfer in Near-Earth Space Associated with Substorms of March 22 and 31, 1979 |
| CDAW 7.0 Data Catalog | The Response of the Magnetotail to Substorm Expansive Phase Activity |

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## MISCELLANEOUS

| | |
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| NSSDC/WDC-A-R&S 81-04 | Modeling the Data Systems Role of the Scientist (for the NEEDS Command and Control Task)† |
| NSSDC 71-05 | Handbook of Correlative Data† |
| NASA SP 7601 | OGO Program Summary |
| NSSDC 71-21 | IMP Series Report/Bibliography† |

## DATA CATALOG SERIES FOR SPACE SCIENCE AND APPLICATIONS FLIGHT MISSIONS

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|---|---|
| NSSDC/WDC-A-R&S 82-21 | Descriptions of Planetary and Heliocentric Spacecraft and Investigations (Volume 1A) |
| NSSDC/WDC-A-R&S 82-22 | Descriptions of Geostationary and High-Altitude Scientific Spacecraft and Investigations (Volume 2A) |
| NSSDC/WDC-A-R&S 83-03 | Descriptions of Low- and Medium-Altitude Scientific Spacecraft and Investigations (Volume 3A) |
| NSSDC/WDC-A-R&S 85-03 | Descriptions of Meteorological and Terrestrial Applications Spacecraft and Investigations (Volume 4A) |
| NSSDC/WDC-A-R&S 86-01 | Descriptions of Data Sets from Low- and Medium-Altitude Scientific Spacecraft and Investigations (Volume 3B) |

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